U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF SOILS—BULLETIN No. 21

MILTON WHITNEY, Chief.

RECLAMATION OF ALKALI LANDS IN EGYPT.

AS ADAPTED TO SIMILAR WORK IN THE UNITED STATES.

BY

THOS. H. MEANS,

IN CHARGE OF ALKALI LAND RECLAMATION, BUREAU OF SOILS.

In cooperation with the Office of Seed and Plant Introduction and Distribution, Bureau of Plant Industry.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1903.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS,
Washington, D. C., March 31, 1903.

SIR: I have the honor to transmit herewith the manuscript of a report on the reclamation of alkali lands in Egypt as adapted to similar work in the United States, by Thomas H. Means, of this Bureau. I recommend that this report be published as Bulletin No. 21 of the Bureau of Soils.

The illustrations, which comprise eight half-tone plates and six text figures, are considered essential to a clear understanding of the text.

Respectfully,

MILTON WHITNEY,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

PREFACE.

The information given in this report was collected by Mr. Thomas H. Means during a visit to Egypt in the summer of 1902, when he was detailed from this Bureau to accompany Mr. Thomas H. Kearney, of the Bureau of Plant Industry, to northern Africa for the purpose of collecting seeds of alkali resistant plants of that region. The expenses of this journey were paid from the fund for Seed and Plant Introduction, under control of the Bureau of Plant Industry. This report is, by permission, published by the Bureau of Soils, to which this particular line of work pertains.

There is in arid America, according to the calculations of Newell, sufficient water for the irrigation of 74,000,000 acres of land, but in 1899 only 7,263,273 acres were irrigated. The field parties of the Bureau of Soils have mapped the soils and studied the alkali conditions of a number of typical irrigated districts, covering over 3,000,000 acres of land. They have found that on the average about 13 per cent of the irrigated lands examined contain alkali in sufficient quantities to be either harmful to the growth of crops or to entirely prevent profitable cultivation. If this ratio holds in the entire area of irrigable lands of the United States (and careful estimates seem to show that it does), then there are over 9,000,000 acres which contain an excess of alkali salts, or which, in the natural course of events, will develop a harmful excess of salts unless there is a radical change in the present methods of irrigation.

The value of this alkali land is nominal, the greater part of it being priced at $10 per acre or less. Were this land in a fertile condition its value under irrigation would be at least $75 per acre. If it can be brought into a state of fertility its value will therefore be increased $65 per acre; and in order that the reclamation may be a commercial success, it must be carried out at a cost below this amount.

The subject of alkali has been a source of much anxiety to our Western people, and the vast injury that has been done through the occurrence of alkali has prejudiced outsiders in irrigation enterprises to such an extent that in many communities the subject has been exceedingly unpopular, and any reference to it in connection with certain localities has been vigorously opposed and criticised.

It must be recognized that alkali occurs in all arid countries, and it is a problem for consideration and suitable control by the people of irrigated arid districts, as the suitable drainage of rice lands or corn and wheat lands has been in other parts of the humid regions.

The experts of the Bureau of Soils firmly believe that the alkali lands of this country can be economically reclaimed and that the damage from alkali is unnecessary and will not result if proper precautions are taken. Furthermore, it is a well-known fact that in most cases alkali accumulates in the most fertile soils, and the presence of alkali in the soils of arid regions should indicate to the people as a rule a high degree of fertility, provided proper methods of handling the soil are adopted.

The publications of this Bureau have been recommending drainage for the reclamation of these waste lands. This recommendation had previously been made by other writers on the subject, and all who have given this matter any thought are unanimous in the opinion that drainage will solve the problem.

As no work of reclamation by drainage has been carried on to completion in this country, it is impossible to say what the actual cost of reclamation would be, but very reasonable estimates based upon the cost of land drainage in the humid States have placed the probable cost of alkali land reclamation at from $10 to $30 per acre. In Egypt large areas have been reclaimed and are now producing crops, and from figures given by the engineers in charge of this work the cost of reclamation can be readily calculated.

The results obtained in Egypt, as will be shown in the following pages, thoroughly warrant the statements made in previous publications of this Bureau as to the practicability of reclamation by drainage, for it will be seen that the cost of reclamation is so low that much of the land of the West now lying idle on account of alkali or seepage water can be made to produce crops in from one to three years, with an expenditure much below the value of the land when reclaimed.

Placing the average cost of reclamation at $20 per acre, the profit in reclaiming an acre of land is $40, or if the 940,000 acres of alkali land now lying below existing irrigation canals are reclaimed the profit will amount to $37,000,000. If proper care is taken in the future extension of the irrigated area in the arid West, practically all of the alkali land can be reclaimed and the rise of alkali in land now fertile can be entirely prevented.

In order to gain an idea of the character of the work which is being done in Egypt, some of the most important pieces of reclamation work will be described in detail and the methods there in use will be made applicable to our own conditions.

The alkali reclamation party of the Bureau of Soils is carrying on certain work in several localities in the West to demonstrate to the people that alkali lands can be economically reclaimed. A tract of 40 acres of land, containing on the average nearly 6 per cent of alkali to a depth of 6 feet, has been taken up on the great flat between Great Salt Lake and Salt Lake City, and through the cooperation of a public-spirited individual and the Utah experiment station this land has been underdrained and was subjected to a single flooding at the end of the past season. The drains have continued to run as the result of this flooding and subsequent rains and snows, carrying off the drainage water, containing between 2 and 3 per cent of salt. It is believed that in spite of the comparatively short irrigation season of that locality, during the present year this land can be sufficiently sweetened to grow a shallow-rooted crop, and that in two years the land will be sufficiently reclaimed to grow any crop suited to the locality.

A similar demonstration is being made in the Central Colony at Fresno, Cal., on a tract of 20 acres. The drains have just been installed and the irrigation waters turned onto the land. Similar work is being started at Yakima, Wash., and it is proposed to start another demonstration work at Billings, Mont. These four places have been selected as centers at which to carry on the work under the belief that the success which it is thought will be attained at those places will be such an object lesson that the method of providing suitable drainage for irrigation lands will be generally recognized and practiced wherever conditions make it necessary.

Milton Whitney.

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AGRICULTURAL DEVELOPMENT OF EGYPT.

The soils of Egypt have been farmed for thousands of years. The date of the reign of the earliest of the Pharaohs is much disputed, but some authorities assert that Menes, the traditional founder of the first dynasty, lived about 5000 B. C. As the country under this dynasty seems to have been in a high state of civilization, one would naturally infer an even earlier period during which this civilization was developed. During the fifth dynasty, three or four thousand years before Christ, agriculture, as shown on tombs and monuments, had reached a state of development which was hardly exceeded until the present century. Even to-day the plow used by the fellah is the same as that pictured upon monuments of the fifth dynasty.

There are in Egypt at the present time 6,250,000 acres of irrigated land, and it is supposed that under the Pharaohs a much larger area was under cultivation, for at the present time one-third of the irrigable land is uncultivated. At the time of the Arabian conquest, in the seventh century A. D., a large portion of Egypt was devastated, the banks of the old basins were broken, and large areas were flooded with salt water or left idle. The land thus abandoned was subject to evaporation from the surface, as a consequence of which over 1,500,000 acres of land have been so damaged by the rise of salt and alkali that their cultivation is no longer possible. These lands lie in a fringe around the lower edge of the Delta, and extend from Alexandria to Suez. The greater part lies below the 3-meter (9.8 feet) contour; a great deal of that between 3 and 7 meters (9.8 and 23 feet) is charged with salt or alkali, while above 7 meters (23 feet) in elevation the land is practically free from salt.

Except for those small areas of land lying too high to be reached by the ordinary floods of the Nile, the ancients used only the basin system of irrigation. This method consists of flooding the land to a depth of from 3 to 5 feet at the season of high Nile, and of maintaining this depth of water for about six weeks, when the water is drained back into the Nile, and the seed is sown, without plowing or other cultivation, on the surface of the newly deposited mud. (See Pl. I, fig. 1.)

In this way but one crop could be grown each year. The higher lands were covered only by the highest floods, or only eight or nine times in a century. During the remaining years these lands were irrigated by lifting the water from the canals or the river. It can readily be seen that there was little opportunity for the accumulation of alkali salts so long as the basin method of irrigation was kept up, for the large amount of water which washed over and through the soil each year either removed the salts or washed them down so deep that the capillary forces were unable to return them to the surface before the next annual flood. Upon the abandonment of this method, however, the movement of soil moisture was entirely from below, and the soluble salts gradually accumulated at the surface. (See Pl. II.) Other considerable areas which lay very near or slightly below sea level were flooded with salt water from the Mediterranean. There are said to be at the present time 1,180,000 acres of land in the shallow salt lakes around the edge of the delta. Most of this land, it is believed, was under cultivation down to the time of the Roman occupation, for the ruins of ancient cities or towns are found upon mounds rising out of these shallow lakes. Moreover, Strabo and Horace sing the praises of the wines raised in the basin of what is now Lake Mareotis. It can not be definitely said, however, that the beds of these lakes were then, as now, below sea level, for the surface of the country may have sunk since that time.

When Napoleon was in Egypt in 1798 and 1799, he is said to have expressed the opinion that the time would come when a dam would be placed across the Nile at the point of division, so that water could be turned either into the Rosetta or the Damietta branch at will, thus doubling the inundation.

Mehemet Ali, who became viceroy in 1805, with his indomitable will and courage changed the method of irrigation in Egypt by cutting a number of deep canals, thus permitting the irrigation of land throughout the year. Cotton was introduced into Egypt about this time, and as this plant can not thrive where basin irrigation is practiced, its increasing importance was a prominent factor in causing the extension of perennial irrigation. The river was so low during the greater part of the year that it required pumping to supply the cotton fields. In 1833 Linant Pasha proposed to construct across the Nile at its point of division a regulating dam, which would allow the floods to pass unchecked, but which, by means of gates, would permit the water to be raised at low Nile to a sufficient height to fill canals running at such a level that irrigation could be practiced without pumping. The construction of this barrage was decreed by Mehemet Ali, but the impetuosity of the man so hastened the work that proper care was not exercised in the construction. The barrage was completed in 1865, but

FIG. 1.—BASIN METHOD OF IRRIGATION.

Formerly all the cultivated lands were irrigated once a year by turning on from 2 to 6 feet of water, which was allowed to stand six weeks and then drained off when the flood subsided. There has never been trouble from the rise of alkali with this method of irrigation. The method did not, however, allow the growing of cotton or more than one crop in the year.

FIG. 2.—DITCHING ALKALI LAND.

The first steps in reclamation of these lands.

ALKALI SPOT APPEARING IN COTTON FIELD.

Cotton can not be grown under the basin method of irrigation, as it requires frequent applications of water throughout the year. It is this change in the practice from basin to perennial irrigation for the production of two or three crops in a season—a method used commonly in the United States—which has resulted in the rise of alkali over large areas in the Nile Valley which had been successfully cultivated for thousands of years previously without damage from this source. Even where the basin method was abandoned, as, for example, after the Arabian conquest, the lands developed alkali and have been unproductive to this time.

was never entirely efficient until 1895, when the water was raised to the desired level. At the present time all of the land of lower Egypt is supplied with perennial irrigation, the greater part of the water being taken out of the Nile at this barrage.

The great advantage of the perennial over the basin method of irrigation can readily be seen. Under the basin method but one crop was possible each year, while under the perennial method two and generally three crops are produced. There is yet a great deal of land under basin irrigation in Upper Egypt, but gradually canals are being dug and the system of perennial irrigation extended. In a very few years practically all the land of Egypt will be under the improved system.

The change from basin to perennial irrigation in Egypt has not been without its misfortunes, for certain areas have been allowed to lie idle pending the completion of canal systems, and alkali has risen. Mr. Willcocks, in his first book on the Irrigation of Egypt, seems to be of the opinion that it will be necessary to return to basin irrigation in order to wash the alkali from these lands. Later practice has shown that the method best adapted to reclamation is essentially basin irrigation; but the basins are small, about 3½ acres in extent. Other writers upon this subject ascribe much of the alkali and salt land to the change in the system of irrigation, and during the transition period this was probably true; but, now that the methods of perennial irrigation are well understood and the causes of the rise of alkali better known, perennial irrigation, while more profitable, is seen to be just as safe, if proper precautions are used, as basin irrigation.

CLIMATE OF EGYPT.

The climate of Egypt is arid. Over the greater part of the country there is practically no rainfall, and in no part is there sufficient rainfall to produce crops without irrigation. The average precipitation at Alexandria is 8.26 inches. At Port Said it is 3.49 inches; at Cairo, 1.06 inches. In upper Egypt, south of Cairo, there are no observations on the amount of rainfall, so that no exact figures can be given. There is, however, less rainfall than at Cairo.

The average temperature is high. The coolest portion of Egypt lies along the coast of the Mediterranean, and the temperature increases as one proceeds south. The table on the following page gives the normal monthly and annual temperature of Alexandria and Cairo, together with normal temperatures at a number of points in the United States for comparison.

Normal monthly and annual temperature.

Month.	Alexandria, Egypt.	Cairo, Egypt.	San Antonio, Tex.	Montgomery, Ala.	Yuma, Ariz.
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
January	58.8	55.0	51.5	48.3	54.1
February	59.4	58.5	55.8	52.7	58.8
March	62.1	63.1	61.9	57.0	64.5
April	65.8	70.3	70.1	65.4	69.8
May	70.7	75.2	74.9	72.8	77.2
June	75.6	81.0	80.7	79.4	84.9
July	80.1	84.0	83.3	81.5	91.5
August	79.9	82.4	82.2	79.8	90.7
September	76.5	77.2	77.5	75.6	84.4
October	73.2	73.9	69.7	65.2	73.0
November	68.9	65.1	59.0	55.2	61.9
December	62.6	58.3	54.9	49.6	56.0
Year	69.5	70.3	68.5	65.2	72.2

The temperature at Alexandria is normally lower than that at Cairo, and is more uniform, the winters being warmer and the summers cooler. There is probably no place in the United States where the temperature conditions correspond exactly with those in Egypt, but a careful examination of the records of the Weather Bureau reveals the fact that a zone through the southern tier of States, extending from San Antonio, Tex., eastward through Montgomery, Ala., has a normal summer temperature very close to that of Lower Egypt. It has been generally supposed that the climate of the country around the mouth of the Colorado River and extending up into the Colorado River Valley in Arizona and California is very similar to the climate of Egypt. Such, however, is not the case. Normal temperatures from Yuma, Ariz., are included in this table, from which it will be seen that there is a great difference between the temperatures of the two countries. Upper Egypt, no doubt, has a desert climate similar to that of Yuma, but meteorological records have not been kept in that part of the country.

The climate of Egypt may be described as subtropical. Slight frosts occur at Cairo and over portions of the Delta and Middle Egypt, but Upper Egypt and a portion of the Delta close to the Mediterranean Sea are said to be frostless. Oranges, date palms, and other subtropical fruits can be grown throughout the country.

Lying as Egypt does in the midst of the greatest desert area in the world, and having so light a precipitation, it has been generally supposed that the climate is that of a desert—that is to say, that the atmosphere is normally very dry. So far as can be said in the absence of continued scientific observations, Upper Egypt and a portion of Middle Egypt have a climate of this type; but the greater part of Egypt and that part in which cotton—the chief agricultural export—is

grown has a climate very different from that of a desert. During the greater part of the year the prevailing wind is toward the south, blowing from the Mediterranean Sea to the land. This wind in its passage over the sea becomes charged with moisture, and thus gives to the atmosphere of Egypt a much higher relative humidity than is found in a true desert climate. The following table gives the mean monthly and annual relative humidity at two stations in Egypt and at a number of places in the United States.

Mean monthly and annual relative humidity.

Month.	Alexandria, Egypt.	Cairo, Egypt.	San Antonio, Tex.	Oklahoma, Okla.	Montgomery, Ala.	Atlanta, Ga.	Yuma, Ariz.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
January	68.0	66.4	65.6	74.5	75.3	76.4	45.4
February	67.0	60.4	63.8	73.0	74.7	73.9	43.8
March	68.0	58.0	62.1	68.3	68.8	68.6	43.0
April	69.0	52.0	67.7	65.3	64.8	62.4	35.1
May	69.0	50.1	69.6	73.0	66.8	65.8	36.7
June	72.0	50.9	67.3	73.2	70.1	71.1	34.7
July	75.0	51.8	64.0	71.3	76.0	76.3	42.8
August	73.0	57.5	65.2	68.8	78.1	77.9	47.7
September	69.0	65.0	68.8	67.8	74.0	75.2	44.7
October	68.0	68.5	63.7	64.5	69.0	68.4	46.2
November	67.0	69.5	65.3	71.0	72.7	73.3	43.3
December	68.0	71.1	62.8	74.1	75.6	75.6	51.4
Year	69.4	60.1	65.5	70.4	72.2	72.1	42.9

There is no place in the United States, so far as records are available, where the normal relative humidity is that of Cairo, Egypt, throughout the year. There are places, however, where the conditions are very close to those at Alexandria, and a large area, coinciding with the area of similar temperatures already referred to, extending from San Antonio, Tex., eastward through Montgomery, Ala., has a summer relative humidity similar to that at Alexandria and intermediate between the humidity at Alexandria and at Cairo. Ninety per cent of the cotton exported from Egypt is grown in the Delta, in a climate intermediate between that of Alexandria and Cairo, and therefore, as far as temperature and relative humidity are concerned, that portion of the United States which lies in a broad zone through central and northern Texas and central Louisiana, Mississippi, Alabama, and Georgia is the most promising territory for the growth of Egyptian cotton.

There is one point of importance regarding the climate of Egypt which is not brought out in the accompanying tables, and that is the great variability of the relative humidity from day to day. There is hardly a month in the year in Egypt, especially in the upper part of the Delta, near Cairo, when the relative daily humidity has not a range

of 70 per cent, or from a very dry to a saturated atmosphere. This great range is not characteristic of the cotton belt in the United States outlined above.

The table also shows the relative humidity at Yuma, Ariz., and a glance will show that the conditions there are totally different from the conditions existing in Lower Egypt.

The mean evaporation from a water surface in Cairo and in three places in the United States is shown in the following table. So far as can be found, there is no point in America where the evaporation during the summer months is the same as that in Egypt, but a glance at the table will show that the evaporation in Cairo lies intermediate between the figures for the cotton belt and those for Yuma, Ariz. The Weather Bureau statistics upon evaporation are very irregular and admittedly not altogether reliable, and it is thought that if observations were carried on with the same kind of instruments in the two countries places of greater similarity would be found.

Comparison of mean evaporation from the water surface in Egypt and in the United States.

Month.	Cairo, Egypt.	San Antonio, Tex.	Montgomery, Ala.	Yuma, Ariz.
	Inches.	*Inches.*	*Inches.*	*Inches.*
January	2.61			
February	3.14			
March	4.92			
April	5.77	4.68	4.81	8.32
May	7.18	5.27	4.24	9.17
June	8.23	4.79	5.83	10.56
July	8.51	6.77	3.65	9.87
August	7.17	6.54	4.27	9.08
September	5.21	4.71	4.12	9.73
October	4.25			
November	2.83			
December	2.43			
Year	62.25			

PHYSIOGRAPHY AND GEOLOGY.

Egypt includes within its borders all of the northeastern part of Africa between 25° east longitude and the Red Sea, and 21° north latitude and the Mediterranean Sea, a total area of about 400,000 square miles. Of this great area only about 10,000 square miles are cultivated and thickly populated. The remainder is desert, with a scanty population and little agricultural interest.

Alexandria, Egypt, is situated on about the same parallel as Jacksonville, Fla. Cairo is on the same parallel as New Orleans, while Assuan, the southernmost town of importance in Egypt, situated at the First Cataract, is on the same parallel as Durango, Mexico, or a few miles north of Habana, Cuba.

The part of Egypt of interest to the farmers of America is confined to the valley and delta of the Nile. The valley of the Nile, or Upper Egypt, extends from the First Cataract, or Assuan, to Cairo, a distance of 550 miles. The valley has an average width of about 5 miles, varying from that up to 10 or 12 miles. It is a trough, cut through almost horizontal Cretaceous and Tertiary sandstones and limestones, in which has been deposited the sediment from the Nile. The sediment varies from 33 to 115 feet in thickness. A typical cross section of the valley shows the land immediately along the river bank to be higher than that near the bluffs which bound the valley. These front lands are only flooded during extremely high water.

The part of the country north of Cairo, the delta of the Nile, is a fan-shaped area with a radius of 125 miles, gently sloping toward the

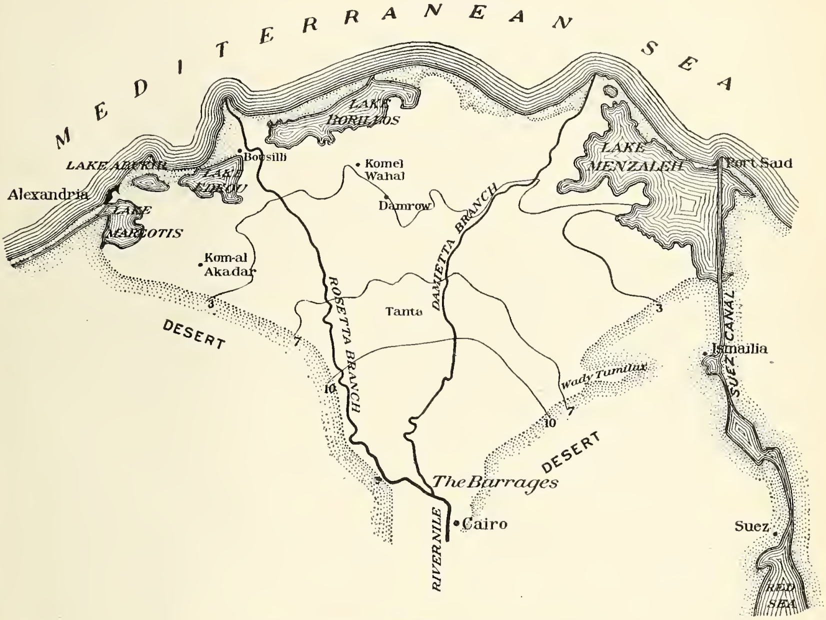


Fig. 1.—Sketch map of the Nile Delta.

sea. Radiating toward the sea from the apex of the delta are gentle ridges which mark the position of present or ancient branches of the Nile. Around the edge of the delta is a series of salt lakes, the bottoms of which lie a few inches or a few feet below sea level. These lakes are separated from the sea by a narrow stretch of sandy beach, cut here and there by a few openings through which the tide ebbs and flows.

The thickness of the layer of Nile mud which forms the soil of Lower Egypt, according to Captain Lyons, director-general of surveys of Egypt, varies from 40 to 60 feet.

A third physiographic province of Egypt is the Fayum, a province lying west of the Nile Valley in an oasis in the Libyan Desert. This province is an oval-shaped basin surrounded by desert hills, connected with the Nile Valley by a narrow opening in the hills bounding the valley on the west. The plateau of the Libyan Desert is at this place 300 to 400 feet above sea level. The depression in these hills slopes from the level of the Nile Valley in a northwesterly direction to Lake Karoun, the remains of the ancient Lake Moeris, which is 140 feet below sea level. The Fayum is watered by a canal, Bahr Youssef, taking water from the Nile at Assiut, and has a desert climate and a very fertile soil.

THE NILE.

The Nile rises in central Africa in a region of heavy rainfall and flows northward across a desert country. The area of the drainage basin of this great river is about 1,200,000 square miles. The two main branches are the White Nile, rising in the great lakes in central Africa, and the Blue Nile, which drains the mountains of Abyssinia.

The White Nile rises in, and flows through, a truly tropical country. The rainfall of this area is fairly high, amounting to 30 or 35 inches each year. The great lakes of central Africa lie along this stream and act as regulators of the discharge. According to Mr. Willcocks, the mean discharge of the river as it leaves Lake Victoria Nyanza is 30,000 cubic feet per second, ranging from 25,000 to 35,000 cubic feet per second during the year. Between this lake and Khartum, where the Blue Nile joins the stream, a distance of 1,620 miles, there are large areas of swamps and lagoons where the river divides and presents a large surface for evaporation.

The mean discharge of the White Nile at Khartum, below the swamps, is 60,000 cubic feet per second, with a minimum discharge of only 7,000 cubic feet and a maximum of 150,000 cubic feet per second. The difference between the minimum discharge at the outlet of Lake Victoria Nyanza and the discharge at Khartum represents the loss which takes place in traversing the great swamp regions of central Africa.

The White Nile is a clear-water stream, as the sediment which enters the stream during the rainy season either settles in the lakes or is filtered out in passing through the great areas of swamp. This swamp or "sudd" region occupies the basin of what was once a lake, but which has silted up sufficiently to permit the growth of water loving vegetation. During the season of low water, and particularly after the first rains, the discharge from these swamps is highly charged with organic matter, giving rise to the "green" water of the Nile in Egypt.

The Blue Nile drains the mountains of Abyssinia. The river has a minimum discharge of 200 or 300 cubic feet per second and a maximum

discharge of nearly 300,000 cubic feet per second. The water of the stream in time of flood is very muddy and gives rise to the "red" water of the Nile—the water so much desired by the irrigator in Egypt, on account of the fertility which this mud adds to the soil.

The only other tributary of the Nile is the Atbara, a stream which enters about 200 miles below Khartum and whose characteristics are very similar to those of the Blue Nile.

The Nile at Assuan, or the First Cataract, where the stream enters Egypt proper, has a normal flow of 100,000 cubic feet per second, varying from a minimum of 7,000 to a maximum of 475,000 cubic feet per second. The rise and fall of the river is very regular, and upon the regularity and height of the rise depends the success or failure of the crops of Egypt. A very low flood, according to Mr. Willcocks, discharges but 210,000 cubic feet per second, and there is a scarcity of water for irrigation; a good flood discharges 350,000 cubic feet per second, and a dangerously high flood, or one of 450,000 cubic feet per second, causes much damage.

The annual rise commences about the 15th of June and the maximum is reached during the month of September. The river continues near its maximum for a period of from ten to thirty days and then commences to subside, reaching its minimum in May or June. The rise at Assuan averages about 35 feet and at Cairo about 25 feet.

During low water, or when the water is practically all coming from the White Nile, there is very little sediment, but during the season of high water, or when the stream is being fed from the Blue Nile, there is more or less sediment of a mineral nature.

The following table, from analyses by Mathey, shows the material in suspension and in solution throughout the year:

Analyses of Nile water by Mathey, 1887.[a]

[In parts per 100,000.]

Constituents.	Jan.-Feb.	Mar.-Apr.	May-June.	July-Aug.	Sept.-Oct.	Nov.-Dec.
In solution:						
Nitrogen, calculated as ammonia	0.016	0.015	0.017	0.056	0.021	0.019
Lime	4.21	4.32	4.27	4.17	4.67	4.64
Potash	.91	.84	2.09	1.91	1.34	1.02
Sulphuric acid	.28	.28	.31	.32	.19	.14
Organic matter	1.32	1.21	1.05	2.40	1.95	1.49
Carbonic acid	3.41	3.63	4.10	3.72	3.04	4.07
Phosphoric acid	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
In suspension	132.4	49.8	142.7	181.9	390.3	291.4

[a] See Annales de la Science Agronomique, Vol. II, p. 340.

It will be seen that the river, at the time of low water, carries but about 50 parts of sediment to 100,000 parts of water. This amount

increases until in September and October there are nearly 400 parts of sediment. The analyses of the material in solution are not complete, but from other sources it seems that at low Nile the amount is greater than at high Nile. The following table gives a complete analysis of the water-soluble constituents of two samples collected at high and low Nile:

Analyses of Nile water taken at high and low Nile, respectively, by the late Dr. Letherby

[In parts per 100,000.]

Constituents.	A.	B.
Actual or saline ammonia	0.0043	0.0014
Ammonia from organic matter	.0071	.0118
Lime	4.422	5.178
Magnesia	1.033	1.029
Soda	.587	1.301
Potash	1.501	.404
Chlorine	.628	1.737
Sulphuric acid	1.837	2.931
Phosphoric acid	Tr.	Tr.
Nitric acid	Tr.	Tr.
Silica, etc	1.129	.671
Organic matter	1.186	3.129
Carbonic acid and loss	4.281	4.091
Total on evaporation	16.601	20.471
Suspended matter:		
Organic matter	18.414	.943
Mineral matter	130.743	3.829
Total suspended matter	149.157	4.772

A. Sample taken August 12, 1874, at high Nile.
B. Sample taken at Boulac May 13, 1875, at low Nile.

The above figures have been disputed, but are nevertheless given, as they may show characteristics of the Nile in an unusual season. Perhaps the most complete records made of the amount of sediment have been recently published by Dr. MacKenzie, director of the School of Agriculture at Ghizeh. The records are published in the Journal of the Khedivial Agricultural Society, vol. 1, p. 99, 1899.

Dr. MacKenzie says in part:

As is well known, the level of the river Nile varies from month to month during the year with unfailing regularity. It is at its lowest during the months of May, June, and early July, and reaches its highest in September. * * * The suspended matter also varies from month to month and varies practically with the height of the river. When the water is at its lowest level the suspended matter is least, and when at its highest level the suspended matter is also greatest.

The table on the next page, made from diagrams published by Dr. MacKenzie, shows the amount of suspended matter in parts per 100,000 of water.

Sediment in Nile water in parts per 100,000.

Month.	1896	1897	Month.	1896	1897
January	29	49	August	100	174
February	25	27	September	166	163
March	20	19	October	135	100
April	16	14	November	90	60
May	13	14	December	63	35
June	17	13	Average	57	57
July	10	11			

Dr. MacKenzie says:

The samples of water for the determination of the suspended matter were taken from the center of the river opposite Ghizeh village. The method adopted was to take an iron tank, of about 1 meter capacity, out in a boat and fill it by means of a hand pump, taking water from 1 meter below the surface. The tank was then allowed to stand two months, after which the clear water was run off by a tap and the sediment air dried and weighed. * * * A sample of water taken at the Kosheshah escape during the discharge of the basin was found to contain 39.5 parts of suspended matter per 100,000. The 39.5 parts contained 34.8 parts of mineral matter and 4.7 parts organic matter.

The amount of suspended matter at the time of filling the basin may be taken as 170 parts per 100,000, and as 40 parts are not deposited the amount of silt left in the basin will be about 130 parts by weight for every 100,000 parts by weight of flood water in the basin.

Dr. MacKenzie calculates on this basis that about 0.04 inch is deposited each year in the basin.

The following analysis by Dr. MacKenzie shows the chemical composition of the sediment at high Nile:

	Per cent.
Insoluble matter and silica	58.17
Potash	.68
Soda	.62
Lime	3.31
Magnesia	2.42
Oxide of manganese	.09
Iron oxide and alumina	24.75
Sulphuric acid	.20
Phosphoric acid	.21
Carbonic acid	1.55
Organic matter, etc.[a]	8.00
	100.00

[a] Containing nitrogen .12

In conclusion Dr. MacKenzie states:

Nile mud does not supply a sufficient amount of nitrogen for the use of "nitrogen-consuming" crops, but the growth of berseem may, in part at least, supply this deficiency.

Nile mud supplies sufficient quantities of phosphoric acid and potash for the growth of fair crops of cotton, wheat, barley, maize, beans, and potatoes, but does not do so for sugar cane, berseem, and berseem hagazi (alfalfa), though if the two latter crops are consumed by cattle on the land they may be left out of consideration.

THE SOILS OF EGYPT.

The soils of Egypt are practically all formed from the sediment deposited by the Nile. Along the borders of the valley and close to the Mediterranean, desert sands and beach sands are mixed with the sediment, but the soils so formed occupy but a small proportion of the total surface of the land.

In the formation of alluvial soils, the most important factors governing the texture of the soil are the distance from the main channel of the river and the velocity of the water which deposits the sediment. The sediment actually in suspension in the waters of the Nile is very fine; nearly all of it would be classed as silt and clay in a mechanical analysis; but along the bottom of the channel coarser sediments are pushed and rolled, and where these bottom sands are exposed on the surface of the ground, as in and along an abandoned channel, the soils are lighter in texture. Another factor which gives rise to the formation of sands is the cementing action of lime, magnesium, iron compounds, which join together the fine grains of silt and clay and form larger aggregates, thus giving the soil a lighter appearance than a mechanical analysis would indicate. This fact has been very clearly brought out in mechanical analyses of soils from American desert lands where calcium and magnesium carbonates were abundant. In New Mexico certain soils were classed in the field as sandy loams, but upon subjecting them to mechanical analysis, where water acts upon the soil for several days, the cementing material was dissolved, the aggregates broken down, and the soil was found to contain enough clay to be classed as a loam or clay loam. The field examination of Egyptian soils shows this cementing process to be developed to a high degree, and soils in the field seem lighter than would be indicated by the mechanical analyses.

The soils of Egypt consist of fine sands, sandy loams, loams, silt loams, clay loams, and clays, grading gradually from one to the other with no sharp boundary lines. The sands and sandy loams are confined to the Nile banks and to the strips of land radiating from the point of the delta like fingers, and which mark the position of ancient arms of the Nile. There are also small areas of these lighter soils scattered here and there through the country wherever the velocity of the water which carried the sediment has been great enough to carry sands in suspension. Thus, in the basins it is common to find patches of lighter soils near the opening to the basins, and heavier soils away from these openings where the waters have flowed with less velocity.

The sandy soils are not considered so valuable as the clay loams and clays. This is in part due to the fact that the sandy areas generally lie high and suffer most in seasons of short water supply and in part to the fact that their fertility is not so lasting.

The silt loams are perhaps the soils best adapted to general farming. They are found throughout the parts of the country visited by the writer, and owe their origin to the deposition of the heavier particles of sediment carried by the floods. Such soils are easy to till, do not puddle or bake, are retentive of moisture, and are of lasting fertility.

Clay loams and clays occupy greater areas than any of the other soils of Egypt. These soils are black in color, very sticky and plastic when wet, and very hard when dry. They bake into hard clods and at times crack into irregular blocks with deep cracks 2 inches wide. The nearest prototype of this soil in America is the San Joaquin black adobe in California, but a comparison of mechanical analyses shows the soil to be very different in ultimate mechanical composition. The Sharkey clay of the Mississippi alluvial lands is similar in character, but contains much less organic matter.

A soil map of Egypt has never been made, so the exact location of the areas occupied by each type, or the relative importance of each, can not be definitely given. Should a soil survey be made and the results mapped, no doubt many facts of great interest would be developed. It would be possible to trace definitely the changes which have taken place in the Nile and its branches. Much information regarding the ancient history of the country and of the canal systems in those times would be gained, besides the inestimable present benefits to the country in the direction and assistance of the development of agriculture. Egypt is almost entirely an agricultural country—thickly settled and intensively farmed. By far the greater part of the area must be devoted to furnishing food for the people, but the remainder of the land will be devoted to crops for export. At the present time cotton is practically the only export, but in the rapid progress of all civilized countries in scientific agriculture this crop must be kept up to a very high standard, or competition of other countries may seriously curtail its markets. Some of the soils of Egypt produce a high grade type of cotton, while other soils produce an inferior grade. Our experience in our own country shows that a soil survey is the basis on which scientific direction of the development of the cotton industry, or in fact of any other important agricultural industry, can best be carried out.

The following table gives the results of mechanical analyses of samples of soils collected in Egypt:

Mechanical analyses of soils from Lower Egypt.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
7538	Abukir tract	Loam, 0 to 6 inches	0.65	0.52	0.40	0.38	18.42	35.66	28.46	16.16
7539	.....do	Loam, 0 to 12 inches	.50	.02	.08	.16	23.34	42.68	21.00	12.52
7547	Busili	Heavy silt loam, 0 to 12 inches.	1.12	.00	.04	.04	.34	7.78	61.04	29.26
7548	.....do	Heavy silt loam, 0 to 12 inches.	1.41	.04	.06	.02	.18	6.00	60.76	32.74
7544	Abukir tract	Clay loam, 0 to 12 inches.	.89	.14	.30	.18	2.32	4.14	35.08	57.44
7545	.....do	Clay loam, 12 to 24 inches.	.69	.00	.10	.06	3.86	15.90	30.72	49.30
7546	.....do	Clay loam, 24 to 36 inches.	1.04	.00	.04	.04	.92	5.76	51.28	41.64
7540	.....do	Clay loam, 0 to 6 inches	.29	.46	.68	.42	6.26	8.26	31.40	51.08
7541	.....do	Clay loam, 6 to 12 inches.	.44	.20	.28	.32	3.52	5.42	37.30	52.48
7542	.....do	Clay loam, 0 to 6 inches	.24	.30	.42	.36	3.68	9.48	28.28	57.02
7543	.....do	Clay loam, 6 to 12 inches.	.83	.20	.56	.24	1.76	8.74	25.76	62.62
7555	Kom-el-Akhdar	Clay loam, 0 to 12 inches.	.45	1.84	5.80	4.20	21.94	15.84	7.48	42.10
7556	Damru	Clay, 0 to 12 inches	2.46	.60	.88	.20	.58	4.98	37.08	55.46
7557	.....do	Clay, 12 to 24 inches	.51	1.28	.24	.26	.72	4.24	26.64	65.82
7558	.....do	Clay, 24 to 36 inches	.92	1.92	.58	.30	.74	3.64	24.84	67.72
7552	Kassasine	Heavy black clay, 0 to 12 inches.	.96	.14	1.76	1.24	2.24	6.38	11.96	75.82
7553	.....do	Heavy black clay, 12 to 24 inches.	.50	.30	1.90	.90	1.60	5.24	12.68	75.40

Mechanical analyses of soil samples from Upper Egypt.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
7550	Fechn Station	Sandy loam, 0 to 12 inches.	0.36	0.0	0.22	0.18	2.18	37.08	51.32	9.44
7549	.....do	Loam, 0 to 12 inches	.93	......	.18	.16	1.34	27.14	54.10	17.08
7551	Fant Station	Black clay loam, 0 to 12 inches.	2.30	.24	.44	.22	.54	1.32	48.40	48.62
7554	Fechn Station	.....do	.90	.54	.44	.30	.98	6.56	36.40	54.16

The most of these samples were collected at points where salt-land reclamation was being carried on. They therefore may differ markedly from the best soils of Egypt in chemical composition, but it is

thought they represent fairly well the mechanical composition of the soils of the country.

The percentage of the various grades of sand is low throughout the analyses, some of the soils containing excessively high percentages of clay. In this respect the analyses are misleading, for, as previously pointed out, all of the soils seem lighter in the field, due to the aggregation of particles by the cementing action of lime and magnesium carbonates. Sample 7552, according to the mechanical analysis, should be an almost impervious clay soil, but in the field this soil was found to be easily drained, perfectly amenable to cultivation, and favorable to plant growth.

A large number of chemical analyses have been made of Egyptian soils. The writer will not attempt to interpret these analyses, for many of them are very conflicting. It seems, however, that the chemical analyses bear out experience in showing that the soils of Egypt are fertile. In some cases large stores of plant food are present, awaiting the action of time to render them available for plant use, yet modern experience is daily showing that the application of fertilizers sufficiently increases the yield of crops to warrant the practice. Imported chemical fertilizers are in use, but the refuse from the ancient cities and towns and in a smaller way from modern towns forms the most important fertilizer in use.

The annual floods of the Nile, under the basin system of irrigation, left in the newly deposited sediment sufficient plant food for the one crop grown, but with the change to perennial irrigation and two or three crops each year the store of reserve plant food is being drawn on and the need of additions from outside has been seriously felt. The practice of fertilizing is becoming more necessary and more general each year, and will continue to be so with the decrease in area of basin land. Nitrogen is not abundant in the river mud, but the growing of Egyptian clover, or berseem, used regularly in rotation, largely makes up for this deficiency.

RECLAMATION OF SALT LAND AT ABUKIR.

Lake Abukir is separated from the Mediterranean by a narrow strip of sand dunes and sandy shore and is situated about 10 miles east of Alexandria. On the west and south is the basin of Lake Mareotis, and on the east Lake Edku. The bottom of Lake Abukir is from 2 to 4 feet below sea level, and before reclamation commenced it was a dry salt plain during the summer months and in winter was covered with a few inches of salt water. (See fig. 2.)

The reclamation of the land in this lake was under consideration for a long time. There were many doubts as to the feasibility of reclaiming such land at a reasonable cost, particularly among the natives of Egypt. In spite of these doubts, in 1888 the Abukir Company, Lim-

ited, was formed with capital raised in England. This company obtained a concession from the Egyptian government of about 25,000 acres of land at the bottom of this lake and immediately commenced the work of reclamation. For the first few years the success of the undertaking was doubtful, but as information regarding the best methods of reclamation was acquired greater progress was made, and at the present time one sees green fields and thrifty crops of cotton, corn, clover, and grass where once was a barren desert. The reclamation work has been a commercial success also, as is attested by the dividends of 5, 20, and 20 per cent declared by the company during the year 1902.

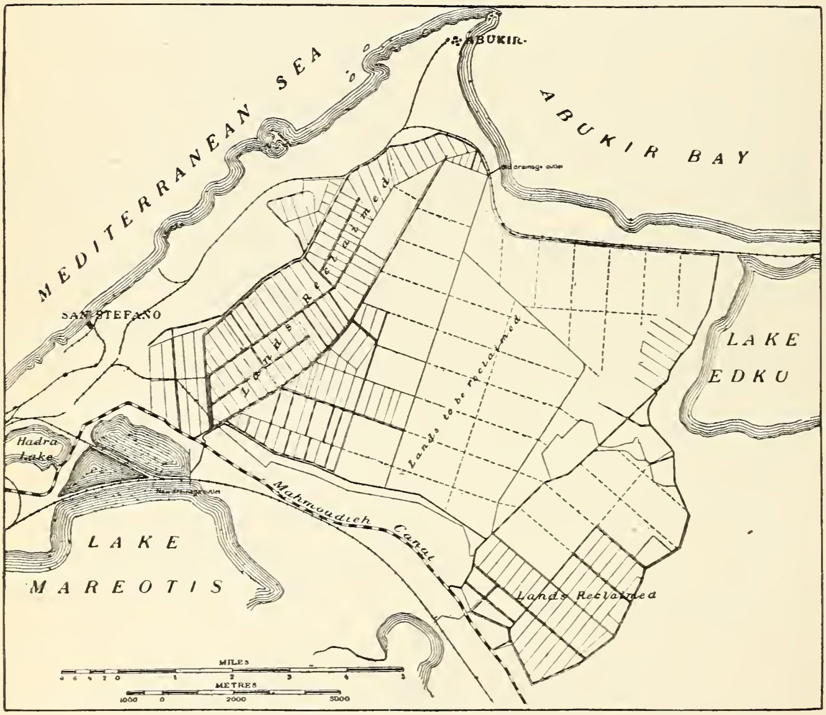


FIG. 2.—Sketch map of Abukir tract.

A part of the original bottom of the lake is yet untouched. The surface is almost level and entirely devoid of vegetation. Samples of this soil were collected by Dr. Volcker before reclamation was attempted. Samples 1 and 2 represent the average character of about 25,000 acres of the lake bottom and contain, respectively, 8.11 per cent and 8.56 per cent of sodium chloride. Sample No. 4 is an average upland soil near by, similar in character to the lake-bottom soil, but containing only 0.01 per cent sodium chloride. This soil is now producing crops each year and is rented for about $25 per acre per year. Attention is called to the high percentage of sodium chloride which

the lake soil contains, sufficient to preclude any possibility of profitable agriculture. Analyses by Dr. Volcker of the sample just cited, excluding materials readily soluble in water, are given in the following table:

Analyses of soil from Lake Abukir.

Constituent.	Sample No. 1.	Sample No. 2.	Sample No. 4.
	Per cent.	*Per cent.*	*Per cent.*
Insoluble silicates and sand	66.23	45.81	54.27
Alumina	6.36	10.88	11.95
Oxide of iron	11.69	11.04	11.71
Iron pyrites	.08	.11	.10
Lime	2.08	7.73	8.03
Magnesia	1.79	.93	.50
Soda	.79	....	.41
Potash	.65	1.23	.67
Sulphuric acid	2.23	2.56	.14
Carbonic acid	.19	4.75	5.59
Phosphoric acid	.16	.19	.38
Organic matter [a]	3.64	6.21	6.24

[a] Sample No. 1 contained 0.035 per cent, sample No. 2, 0.07 per cent, and sample No. 4, 0.096 per cent of nitrogen.

In August, 1902, the writer collected a series of samples of this soil upon the unreclaimed lake bottom. Analyses of these samples (Nos. 7544, 7545, and 7546) made by Breazeale in the laboratory of the Bureau of Soils are shown in the following table:

Analyses of soils from Lake Abukir.

Constituent.	7544, 0 to 12 inches.	7545, 12 to 24 inches.	7546, 24 to 36 inches.	7538, 0 to 6 inches.	7539, 0 to 12 inches.	7540, 0 to 6 inches.	7541, 6 to 12 inches.	7542, 0 to 6 inches.	7543, 6 to 12 inches.
Ions:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Calcium (Ca)	15.45	2.68	1.44	13.46	10.12	17.18	9.72	9.16	0.0
Magnesium (Mg)	Tr.	Tr.	Tr.	Tr.	3.73	Tr.	11.87	Tr.	Tr.
Sodium (Na)	17.63	33.18	34.62	15.35	15.17	7.73	6.37	18.34	27.91
Potassium (K)	1.65	2.48	2.61	4.82	4.61	8.24	3.59	5.89	6.09
Sulphuric acid (SO_4)	34.65	12.32	8.78	46.54	32.97	53.62	7.98	41.27	44.58
Chlorine (Cl)	30.06	48.41	50.79	14.17	30.11	6.01	57.51	12.24	7.58
Bicarbonic acid (HCO_3)	.56	.93	1.86	5.66	3.29	7.22	2.96	13.10	13.84
Conventional combinations:									
Calcium sulphate ($CaSO_4$)	49.10	9.12	4.89	45.68	34.30	58.25	11.29	31.00	......
Calcium chloride ($CaCl_2$)	2.77	......	......	......	......	......	17.76	......	......
Magnesium sulphate ($MgSO_4$)	......	......	......	......	10.98	......	......	......	......
Magnesium chloride ($MgCl_2$)	......	......	......	......	5.93	......	46.54	......	......
Potassium chloride (KCl)	3.13	4.72	4.96	9.23	8.79	12.54	6.86	11.14	11.52
Potassium bicarbonate ($KHCO_3$)	......	......	......	......	......	4.30	......	......	......
Sodium chloride (NaCl)	44.23	76.18	79.71	16.17	35.50	......	13.57	11.36	3.52
Sodium sulphate (Na_2SO_4)	......	8.70	7.89	21.13	......	18.56	......	28.60	65.98
Sodium bicarbonate ($NaHCO_3$)	.77	1.28	2.55	7.79	4.50	6.35	3.98	17.90	18.98
Per cent soluble	10.54	9.01	5.80	1.69	1.82	1.16	4.11	.92	1.47

The average percentage of soluble matter in the surface 3 feet of soil is about 8.5. Of this a portion is calcium sulphate, or gypsum, a mineral but slightly soluble in water and more beneficial than harmful in the soil. If the percentage of calcium sulphate is deducted from the average, the percentage of soluble salts to a depth of 3 feet is 6.3, or about 380 tons per acre to that depth.

The soil of the lake bottoms is typically a heavy, dense, sticky black clay, apparently very impervious to water and one which would be difficult to underdrain. In fact, the whole aspect of the land is one of utter hopelessness, and none but the most sanguine of agricultural engineers would have undertaken its reclamation. There are, however, in the lake bottom areas of lighter soil which are easier of reclamation but are not so fertile after the reclamation has been effected.

The greater part of the lake bed is underlain by a sand similar in character to the beach sand immediately to the north.

The table on page 25 shows the mechanical analyses of samples of soil collected from this lake bed.

CONSTRUCTION OF CANALS AND DRAINAGE DITCHES.

The first step toward reclamation is the construction of canals for irrigation and of ditches for underdrainage. Irrigation water is taken from the Mamoudieh Canal by a large canal which subdivides and ramifies over the entire area to be irrigated. The main drain discharges into Lake Mareotis through a siphon under the Mamoudieh Canal. The water from Lake Mareotis is pumped into the Mediterranean by a large plant operated by the Egyptian government at Mex, about 10 miles southwest of Alexandria. This pumping plant maintains the level of the water in Lake Mareotis at about 8.2 feet ($2\frac{1}{2}$ meters) below sea level. The original plan for the drainage of Lake Abukir provided for a pumping station on the coast, at the old outlet of the lake on the north, but this station has now been abandoned. (See fig. 2.)

The accompanying plans show two methods of placing the canals and drains, both of which are in general use.

By the first plan (fig. 3) the secondary drains run halfway between the secondary canals and into them the tertiary drains, or laterals, run from each side. These tertiary ditches are 150 meters (492 feet) long, 80 centimeters ($31\frac{1}{2}$ inches) deep, 25 centimeters (9.8 inches) wide at the bottom, and 125 centimeters (49 inches) wide at the top. The distance between the drains is 50 meters (164 feet). These lateral drains subdivide the land into areas 150 by 50 meters (492 by 164 feet), containing about 1.83 acres. This tract is called a "gata," and is the unit used in renting the land.

The second plan (fig. 4) shows the system of canals and drains in use in other parts of the reclamation work. The main difference

between this and the first plan is that the secondary drains run beside the secondary canals and serve as infiltration drains to catch the water which seeps from these canals, and the tertiary drains are 300 meters (984 feet) long, or twice the length of the drains in the first plan. It will be seen that in this plan a smaller amount of ditching is necessary,

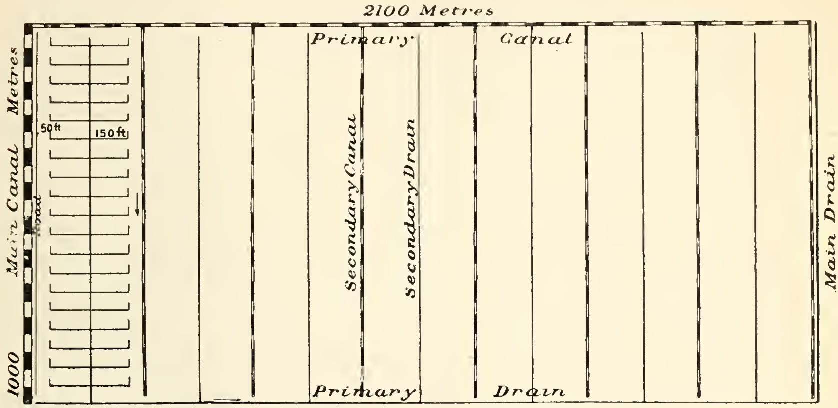


FIG. 3.—Plan of canals and drains, Abukir tract, where secondary drains are midway between secondary canals.

and where the land has the requisite fall to permit the use of such long drains this system is to be recommended.

The land is so nearly level that very little fall can be given the canals and drains. The main drains and canals have a fall of 1 in 20,000, or about $3\frac{1}{6}$ inches to the mile; the laterals and sublaterals are

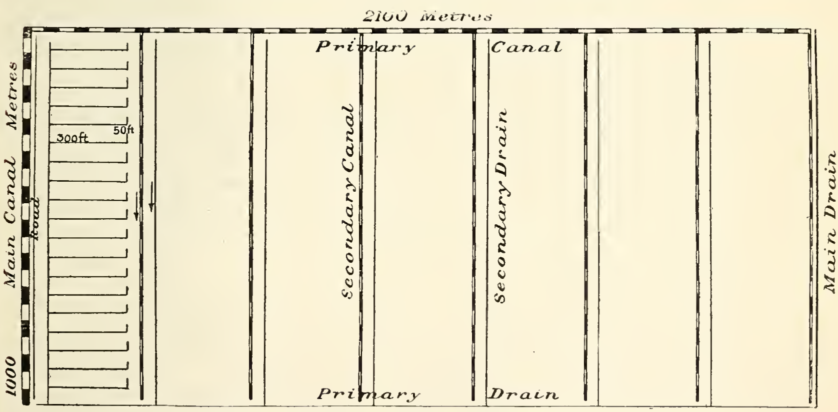


FIG. 4.—Plan of canals and drains, Abukir tract, where secondary drains are beside secondary canals.

almost level. The cost of this canalization amounts to about $12.50 per acre. This includes not only the cost of construction of canals and ditches, but also expenditures for pumping plant and the general expenses of the company, such as buildings, machinery, superintendence during construction of the works, etc.

LEVELING THE LAND.

One of the most essential parts of the reclamation system is the leveling of the land so that each field or "gata" will be perfectly level, and when flooded uniformly covered. There are two methods of leveling in use at Abukir. The first method is to use scrapers drawn by bullocks or buffaloes. These scrapers are very similar to the common scoop scraper in use in this country, but are of wood braced and protected by iron bands and with an iron cutting edge. Work with these is slow and laborious, but where labor is as cheap as in Egypt, and where it is so difficult to teach the natives to handle improved machinery, these homemade scrapers have proved very successful.

The second method of leveling is that of leveling under water by drawing a long board, on which the driver stands, across the field while it is flooded with water to a depth of 3 or 4 inches. This method is cheaper than the first method, but can not be used the first year the land is flooded, because the soil is then very soft and boggy.

FLOODING THE LAND.

After the canals and drains are dug and the land is sufficiently level to permit uniform flooding, water is turned into each gata to a depth of 4 inches. When possible this depth is maintained until the land is ready for a crop, but during the season of low water in the Nile the use of water for reclamation purposes is not permitted, so that there are times during the year when this land has to remain dry.

During the time the water remains upon the land the salt which the soil contains is dissolved and carried away by the drainage water. The drainage water is very salt and is said to contain at times over 10 per cent of sodium chloride.

On some of the land one season's washing is sufficient, but as a rule the land is washed two years before the soil is sweetened sufficiently to permit crop growth. If the first season's washing has not sufficiently sweetened the land, it is plowed during the summer months, when water is not abundant, in order to reduce the surface evaporation to a minimum.

At the end of the second year the land is usually sufficiently sweetened for some crop. Samples of the soil are examined for the percentage of sodium chloride content, as experience has shown that this is an indicator of the condition of the land as regards crop growth. The first crop to be grown is barnyard grass (*Panicum crus-galli*), called by the natives "dineba." The seed of this plant is obtained from the screenings from the rice mills, and as it is a by-product it is very cheap. If the growth of this grass is good, the soil is considered in a condition for the introduction of other crops, and as a rule Egyptian clover is then planted. While these crops are on the ground the

land is heavily flooded, as much water being used as the plants will stand, so that there is no opportunity for the alkali that has been washed down to return to the surface.

The "dineba" is planted upon the flooded land, and the crop generally remains upon the ground for six weeks or two months. It is then either pastured by sheep or stock or is cut by hand and fed green. As the land sweetens salt weeds and bushes begin to grow vigorously, so that it is necessary, after cutting the "dineba," to go over the fields and clear them of this brush. The land is then flooded and sometimes harrowed, and as the water soaks away Egyptian clover seed is sown upon the wet surface. Clover occupies the ground during the fall and early winter months, and if its growth is satisfactory cotton is planted the following winter. When cotton can be successfully grown the land is considered to be fully reclaimed. This rotation is the one in general use, but at times other crops, such as corn and sorghum, are introduced.

In order to determine the percentage of salt which these crops will withstand, a number of borings were made and the samples examined. It was found that, on the average, "dineba," or barnyard grass, will not withstand more than 0.6 per cent of soluble matter in the first foot of soil. Egyptian clover requires the first foot to be even freer of salt, while Egyptian cotton has been found growing in soil that has as high as 1 per cent of salt in the surface foot. Mr. Lang Anderson, manager of the Abukir work, says:

> With 2 per cent of salt in the soil a fair crop of dineba can be grown. With 1 per cent it attains its full height. For berseem, or Egyptian clover, the percentage of salt should not exceed 0.5 per cent, and about the same for "sabini" rice.

The difference between these figures and those obtained by the writer is probably due to the fact that Mr. Anderson collected his samples to a greater depth and included some of the subsoil still charged with salt.

From all the information which could be gathered it seems that the value of barnyard grass and Egyptian clover as reclamation crops is not due to the fact that they are able to withstand a large amount of salt, but to the fact that they are very shallow rooted, growing in the immediate surface soil which has been washed free from salt, and are adapted to a very wet soil. Egyptian cotton, however, is a deep-rooted crop, its roots growing down into the subsoil, which is still charged with salt. Therefore the Egyptian cotton is actually more resistant to salt than the other two reclamation crops, though the best grades of cotton are not produced on salt lands.

The total cost of this reclamation work is given as $18.30 per acre, but it varies from this amount up to $25 or $30 per acre. This latter amount, however, includes the cost of the original purchase of the land, cost of live stock, tools, buildings, taxes, water distribution,

management, seed, harvesting, and all expenses incident to the work. It will be seen that the greater part of these expenses would be incurred in taking up new land anywhere, and should not be included in the cost of actual reclamation from salt. It is very difficult to obtain figures as to the actual cost of ditching, washing, and farming until the land can be made to pay expenses and a reasonable interest on the capital invested, but it is thought that this figure does not exceed $15 per acre.

It should be remembered that the cost of labor in Egypt is very low. The ordinary farm laborer receives $5 per month, and labor by the day is paid 10 or 15 cents. Women and children take part in the minor field operations and receive from 3 to 5 cents a day. Such labor is, however, not as efficient as American labor, and the difference in cost is not so great when this fact is considered. The engineers in charge of the Abukir reclamation estimate the cost of digging the lateral ditches at 3 cents per cubic yard, a figure much below that for similar work under American conditions; but where tile are used our ditching can be done as cheaply, for ditches for tile are not dug so wide as open ditches and our workmen are more efficient.

Thoroughly reclaimed land is worth from $200 to $300 per acre, the latter price having been refused for a large tract recently reclaimed at Abukir. Much of the newly reclaimed land is being rented to individual farmers at from $10 to $30 per acre per year, depending upon the state of the reclamation.

RECLAMATION OF ALKALI LAND IN WADY TUMILAT.

Wady Tumilat is a shallow depression in the desert hills to the northeast of Cairo, and is separated from the Delta proper by a triangular area of sand hills. This depression probably at one time was occupied by an arm of the Nile, but in historic times the only water channel known was a canal from the Nile to the Red Sea, built by one of the Pharaohs about the fourteenth century before Christ. The wady is a part of what was probably the Land of Goshen, assigned to the Israelites during their stay in Egypt.

Fig. 5, reduced from a map kindly furnished by Mr. J. Langley, inspector of irrigation, who has had the direction of the reclamation work, shows the lowest part of the wady at a point where it is cut across by a line of sand hills. At this point is located the pumping station, which raises the drainage water into a canal high enough to cross the dunes. The areas inclosed by dotted lines were under cultivation before reclamation work was undertaken. As late as 1858 all the area of the wady was under cultivation. In that year the Sweetwater or Ismailia Canal was dug from the Nile near Cairo to supply the towns and workmen along the Suez Canal. This canal follows the northern margin of the wady, its bed being excavated in the sands and

gravels of the edge of the desert hills. The surface of the wady is covered with a deposit of Nile mud from 2 to 8 feet deep, but underlying this heavy soil is the same sand and gravel as is found in the canal and hills on each side.

The canal loses much water by seepage through the porous bed. The water passes downward into the sands and flows laterally under the wady and to the surface in the lower parts. The water carries in solution only moderate quantities of soluble matter, but the evaporation of this water from the surface of the soil has given rise to an excess of soluble salts great enough to prevent profitable agriculture on much of the land. In 1897 probably 50 per cent of the area was out of cultivation. Much of it was under water part of the year and was a favorite

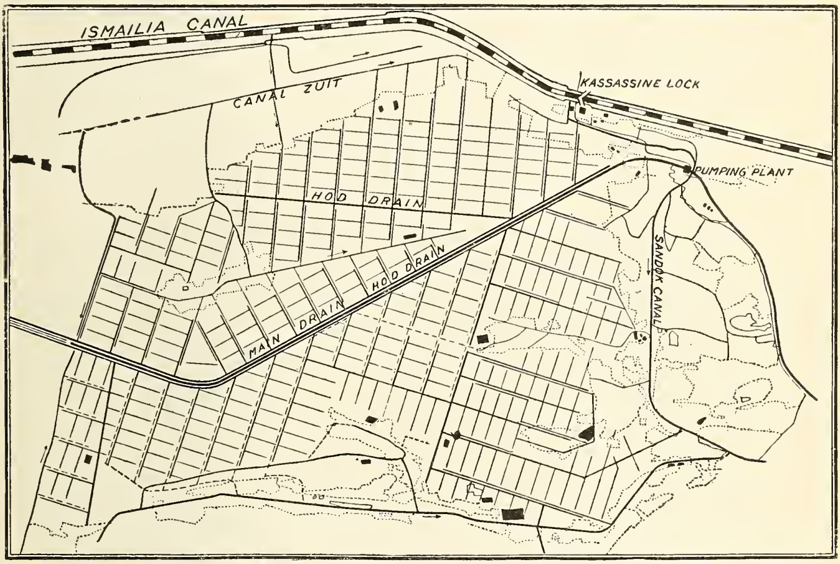


Fig. 5.—Sketch map of the east end of Wady Tumilat.

resort for duck and snipe hunters. Other parts were covered with a heavy coating of salt or alkali. In that year Mr. J. Langley, inspector of irrigation, first circle, was placed in charge of the reclamation of the wady, and steps were at once taken to bring the swampy and alkaline lands again under cultivation. The system of drainage adopted is very similar to that in use in the reclamation work at Abukir, but there are several modifications to fit the local conditions.

The accompanying sketch (fig. 5) shows the plan of drains and canals over the eastern portion of the wady. The distance between the laterals or tertiary drains is 100 meters (328 feet) by 250 meters (820 feet). The depth is 80 centimeters (31.4 inches). In better ground the distance is 150 meters (492 feet) by 250 meters (820 feet). These tertiary

drains end in secondary drains of adequate capacity. In these and in all larger drains the aim is to keep the water surface in the ditch at least 1 meter below the surface of the soil. The main drain is 40 feet wide at the bottom, with a fall of 1 in 20,000, or 5 centimeters per kilometer (3.1 inches per mile). The upper portions of this main drain consist of two 20-foot drains side by side. This arrangement is to permit the cleaning of one while the other is being used.

The water from the main drain is lifted almost 2 meters (6.6 feet) in order to carry it over a series of sand hills between the wady proper and the salt lakes lying along the Suez Canal. This pumping plant, the location of which is shown on the map, consists of two 30-inch centrifugal pumps and one 20-inch pump, run by direct-connected double-expansion engines. The total capacity of the pumping plant is about $2\frac{1}{2}$ cubic meters (88 cubic feet) per second. The area drained comprises about 18,400 acres, so that if the plant works at its maximum capacity it can remove 0.11 inch of water from the wady in twenty-four hours, or about $174\frac{1}{2}$ acre-feet of water. The estimated expense of the pumping plant is $20,000 per year, which makes the cost of lifting 1 acre-foot $6\frac{1}{2}$ feet 31 cents, or 4.8 cents per acre-foot per foot of lift.

The water to be pumped is not only derived from underdrainage, but also to a large extent from surface drainage and waste from the canals. At the present time, when much land is being washed and rice and samar are extensively grown, the amount of water to be drained away is great, but when the reclamation is completed and a larger area is in cotton and more attention is given to reducing the waste the quantity of water to be lifted will be greatly diminished.

At one time one important source of seepage water was the lateral canals running across the wady from the main canal on the north to the southern limits of the area. These laterals running through the lowest portion of the wady on elevated ridges or terrepleins cut off all surface drainage, and by their high level contributed much toward the accumulation of seepage water below. An important aid in reclamation was a change in this canal system, by which lateral canals were replaced by canals running along the south side of the wady, having parallel infiltration drains, or seepage drains as they would be called in America. These have proved of great use in certain cases in catching water which would subirrigate land lower down. In the case of the Wady Tumilat, however, the substratum is so porous that the infiltration drains are of little use, as the water runs beneath them and appears lower down. Another feature of great assistance in the reclamation is the Nile mud in the Ismailia Canal. This mud has so thoroughly choked up the pores of the underlying sand that the loss by seepage is now quite small.

As soon as drains and canals are dug the land is rented to natives at a nominal figure, usually \$1.25 per acre per year. This rent is increased to \$2.50 the second year and \$3.75 the third year. At the end of the third year a new valuation of the land is made and the rental greatly increased.

The soil of the wady is typically a dense black clay, deposited by the Nile floods. A mechanical analysis is given on page 22. When dry the soil cracks much as does the San Joaquin black adobe of California; when wet it is sticky and dense and puddles easily. Underlying this heavy soil is a subsoil of sand, sandy loam, or gravelly sand. The depth to this porous substratum varies from 1 foot to 6 or 8 feet. The higher portions of the land possess a lighter soil, for here the sand of the desert hills on each side is mixed with the Nile mud.

The mechanical analysis which appears on page 22 is from an average sample of the heavy black clay. The soil contains an abnormally high percentage of clay, but seems to be a lighter soil in the field than the analysis indicates.

The character of the alkali which damages these soils is shown in the table following:

Chemical analyses of soils from Wady Tumilat.

Constituent.	7561. 0 to ½ inch.	7552. 0 to 12 inches.	7553. 12 to 24 inches.
Ions:	*Per cent.*	*Per cent.*	*Per cent.*
Calcium (Ca)	0.18	1.65	4.47
Magnesium (Mg)	.02	Trace.	Trace.
Sodium (Na)	35.22	24.12	19.49
Potassium (K)	1.38	6.97	7.98
Sulphuric acid (SO_4)	25.12	19.38	5.11
Chlorine (Cl)	23.41	9.94	11.19
Bicarbonic acid (HCO_3)	4.35	37.94	51.76
Carbonic acid (CO_3)	8.67	....	....
Nitric acid (NO_3)	1.39	....	....
Phosphoric acid (PO_4)	.26	....	....
Conventional combinations:			
Calcium sulphate ($CaSO_4$)	.63	5.55	7.03
Calcium chloride ($CaCl_2$)	....	....	7.03
Sodium chloride (NaCl)	36.53	6.02	....
Potassium chloride (KCl)	2.64	13.23	14.69
Sodium sulphate (Na_2SO_4)	36.43	22.93	....
Magnesium sulphate ($MgSO_4$)	.08	....	....
Sodium bicarbonate ($NaHCO_3$)	5.99	52.27	71.25
Sodium carbonate (Na_2CO_3)	15.34	....	....
Sodium phosphate (Na_3PO_4)	.45	....	....
Sodium nitrate ($NaNO_3$)	1.91	....	....
Per cent soluble	44.51	1.69	.63

Sample No. 7552, with its subsoil, No. 7553, was collected near kilometer 7, on the main drain. It is the sample for which the mechanical analysis is given in a preceding table. Sample No. 7561 was collected near kilometer 8 and represents the character of the alkali crust in one of the spots found so difficult to wash free from alkali. The most prominent characteristic of the alkali analyses is the presence of a large quantity of soluble bicarbonates which, in the crust, where drying and aeration have taken place, have partly reverted to the carbonates. The sodium carbonate is black alkali, found here only in small spots of less than an acre in extent, though one would expect a much wider distribution when the relatively high proportion of the bicarbonates so generally present is noted.

CROPS GROWN DURING RECLAMATION.[a]

Crops are generally planted the first year of reclamation. In soils where the alkali content is high, it is necessary to wash the land six months or a year. The first crop planted is samar (*Cyperus laevigatus*), a rush used for mat making. (See Pl. III, fig. 2.) This plant is set out at intervals of 18 inches and is kept constantly under water, much as rice is grown. It has an advantage over rice in that it can go without water for a period of ten or twenty days and suffer no damage. Where the land is very salty a poor stand and yield is often the result, but almost invariably the plant yields enough to be profitable, and where good yields are secured the product is worth from $50 to $75 per acre. As stated, in nearly every case a profitable crop of samar is obtained the first year. On the worse land, however, it has sometimes been necessary to wash the soil a full year before a crop could be grown. This is particularly true of those spots which contain sodium carbonate or black alkali.

After a crop of samar has been grown, the land is in much better condition and various crops are then planted, according to the taste of the cultivator. Rotations have been adopted for use during the reclamation, of which the following have proven useful and successful:

First. Where the land is strongly alkaline: 1, washing; 2, samar; 3, cotton. The growth of the cotton indicates the extent to which the reclamation has gone. If a good stand is had and a yield of good fiber is obtained, a new rotation is planned to suit the farmer's taste. If cotton does not do well, the land goes again into samar and receives a further washing.

Second. In land which contains an average amount of alkali: 1, samar; 2, rice; 3, cotton; or, 1, rice; 2, samar; 3, cotton.

[a] For a fuller discussion of this subject see article on Crops used in the Reclamation of Alkali Lands in Egypt, by Kearney and Means, Yearbook Dept. Agr., 1902, p. 573.

Third. In land which does not contain a large excess of soluble salts, cotton comes earlier in the rotation and is followed by less resistant crops, as: 1, samar; 2, cotton; 3, corn. For a number of years after the reclamation has gone on, it will be found advantageous to grow either rice or samar every three or four years, in order to wash from the soil the alkali which has risen above the drains.

COST OF RECLAMATION.

There are 18,400 acres of land in the wady. Upon this £E.45,000[a] ($225,000) have been spent since 1899, and before that time probably £E.27,000 ($135,000) had been spent, making a total of £E.72,000 ($360,000), or at the rate of $19.56 per acre. This total sum includes all expenses of remodeling canals, digging drains, and installing pumping station, and all operating and maintenance expenses.

Between 1881 and 1889 the average rental of the land was £E.15,047 ($75,235), with a maximum during those years of £E.20,587 ($102,925). In 1902 the rental was £E.22,000 ($110,000), and it is estimated that the rental for 1903 will be £E.26.500 ($132.500), or an increase of £E.10,750 ($53,750) brought about in five years by the use of $225,000. It is estimated that when the wady is thoroughly reclaimed the yearly rental will be £E.35,000 ($175,000), or almost two and one-third times its rental previous to the commencement of systematic reclamation.

The cost of ditching per cubic yard can be calculated from the following contract prices for carrying on the work:

Main canals	$0.06½
Main drains	.10⅓
Primary drains	.04½
Secondary and tertiary drains	.03⅘

One of the greatest obstacles to more rapid reclamation has been the lack of population. With the deterioration of these lands the fellahs left the wady, and the repeopling of the villages is slow. For a time the fellahs had little faith in alkali-land reclamation, but gradually the success of the method of reclamation became evident, and now settlers are easier to obtain.

RECLAMATION WORK AT DAMRU.

One of the most interesting, and what will, it is thought, be one of the most valuable experiments in reclamation of salt lands, is that being carried on by M. A. Souter, engineer in chief of the state domain, near Damru. The experiments were started in September, 1902, and the writer visited the property in October, so that nothing can be said

[a] The pound Egyptian, usually written "£E.", is valued at 6½d. more than the pound sterling.

at this time of the final results of the experiments. A plan of M. Souter's work is shown in fig. 6.

These experiments were planned to show the relative efficiency and cost of the three most important methods of reclamation in use in Egypt, namely: 1, colmatage or warping: 2, open drains; 3, tile drains.

Each of these methods is being tried on about 30 acres of land. On the first area there are no drains except those around the outside of the field, which are designed more as surface drains than as underdrains. Muddy water from the Nile is run on this land, allowed to settle, and then drained off. Then more water is run on and the process repeated. In this way large quantities of water are run over the surface of the soil and a coating of mud is deposited. (See Pl. IV.)

On the second plot open drains are being tried. These drains are 75 cm. (29.5 inches) deep and 330 meters (1,082 feet) long, the distance

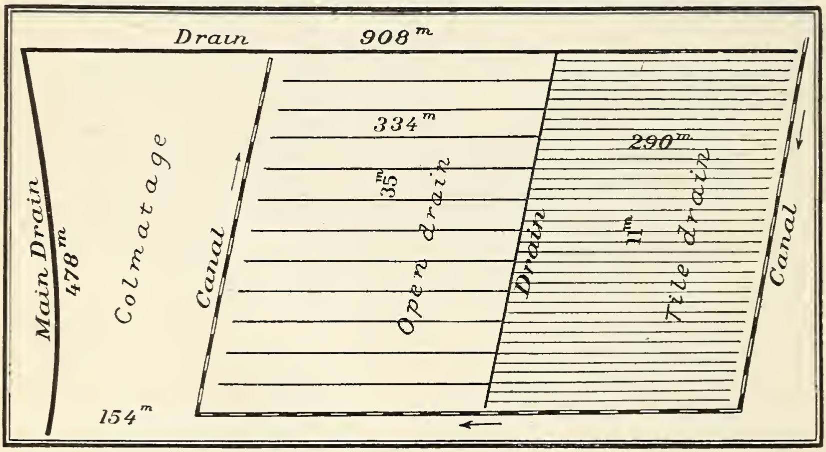


Fig. 6.—Plan of drainage experiment at Damru.

between them being 35 meters (115 feet). This system compares with the majority of the reclamation schemes seen in Egypt, such as those at Abukir, Wady Tumilat, Kom-el-Akhdar, and Kom-el-Wahal. M. Souter places the cost of the installation of this work at from $10 to $15 per acre. (See Pl. I, fig. 2.)

In the third field tile drains have been installed. Since good tile is not procurable in Egypt, M. Souter imported 12 cm. (4¾ inches) tile, in lengths of 50 cm. (20 inches), from Marseille, France. The tile are placed 11 meters (36 feet) apart, at an average depth of 75 cm. (29.5 inches). The tile drains are 250 meters (820 feet) long and have a fall of 6 in 10,000, or about three-fourths of an inch per 100 feet. M. Souter places the cost of this work at $30 per acre.

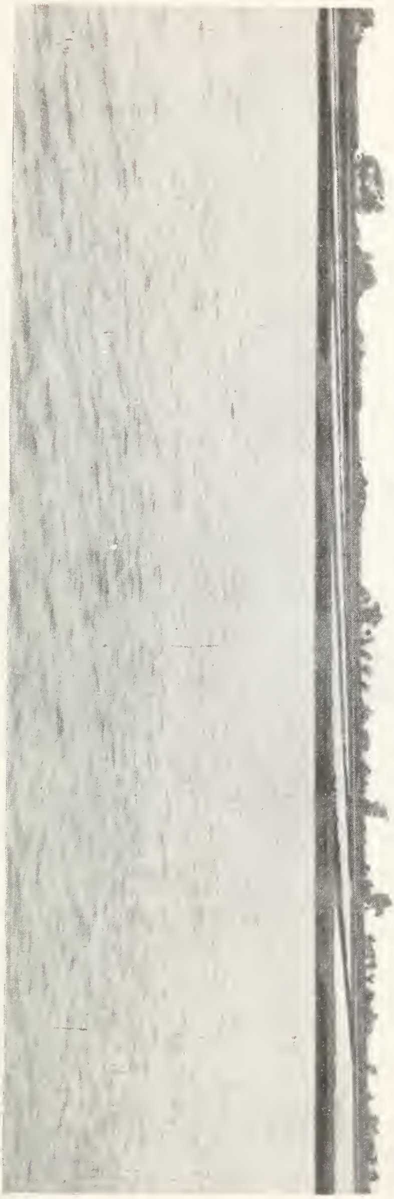
When visited the land had been under water fourteen days. All the drains were running full of water, and the water from the field under

FIG. 1.—MAIN DRAINAGE DITCH IN WADY TUMILAT, USED IN MODERN METHODS OF RECLAMATION.

These ditches are run parallel, so that one may be emptied for cleaning while the other carries the drainage waters.

FIG. 2.—SAMAR, A SHALLOW-ROOTED CROP, ON ALKALI LAND.

The alkali is being washed from the soil by flooding while the crop is growing. Samar is used for making mats and rugs.



FLOODING LAND IN RECLAMATION WORK.

After the alkali lands are leveled and properly ditched for draining, water is turned onto the lands properly checked into small fields, to a depth of 4 inches and maintained for several months, the drainage ditches carrying off the seepage water and salt.

colmatage was running off very clear. The water was all distinctly saline to the taste, and large quantities of salt were being removed. M. Souter sampled the first water coming from the drains and found that it contained 2.5 per cent of sodium chloride.

The tile drains were running full and together were discharging about 1 cubic foot per second. At this rate 2.8 tons of salt were being removed per hour, and as the analyses given below show the average salt content to a depth of 3 feet to be 5 per cent, the drains will have removed all of the salt in one hundred and thirty-three days. This is certainly a much more rapid rate than has been attained in any other piece of reclamation work; but M. Souter's tile are placed very close together and for that reason their efficiency should be high.

The chemical composition of three samples of soil collected in 1-foot sections to a depth of 3 feet is shown in the following table:

Chemical analyses of soil from Damru.

Constituent.	7556, 0 to 12 inches.	7557, 12 to 24 inches.	7558, 24 to 36 inches.
Ions:	*Per cent.*	*Per cent.*	*Per cent.*
Calcium (Ca)	3.43	3.10	3.71
Magnesium (Mg)	1.60	1.61	1.61
Sodium (Na)	29.12	30.09	28.90
Potassium (K)	4.27	3.64	2.53
Sulphuric acid (SO_4)	6.05	5.19	17.06
Chlorine (Cl)	53.89	55.59	44.60
Bicarbonic acid (HCO_3)	1.64	.78	1.59
Conventional combinations:			
Calcium sulphate ($CaSO_4$)	8.65	7.33	12.59
Magnesium sulphate ($MgSO_4$)	....	....	8.00
Sodium sulphate (Na_2SO_4)	....	....	2.62
Calcium chloride ($CaCl_2$)	2.25	2.66	....
Magnesium chloride ($MgCl_2$)	6.29	6.33	....
Potassium chloride (KCl)	8.13	6.93	4.80
Sodium chloride (NaCl)	72.43	75.71	69.85
Sodium bicarbonate ($NaHCO_3$)	2.25	1.04	2.14
Per cent soluble	5.85	4.58	4.57

It is thought that this set of samples is typical of the large area of alkali and salt land being reclaimed in Lower Egypt. A number of other places were visited, but conditions seemed so nearly like those at Damru that samples were not collected, except at Kom-el-Akhdar. The analyses from this place are given on page 22, and a comparison with the Damru samples will show that the similarity deduced from field examinations actually exists.

RECLAMATION WORK AT KOM-EL-WAHAL.

Probably the most extensive attempt at salt land reclamation in Egypt is that by the Societé Anonyme du Behera. In 1894 this company purchased from the Daira Sania, at a cost of £E.240,000

($1,200,000), 123,000 acres of land, the most of it lying in the lower and northern part of the Delta, between the two branches of the Nile. At the time this land was bought practically all of it was out of cultivation, due to excess of water and salt. Since 1894 small tracts have been sold, and at this time the company holds about 115,000 acres.

The system of reclamation is very similar to the one in use at Abukir, and consists of canalization, leveling, flooding, and growing dineba or barnyard grass as the first crop. (See Pl. V.)

The land is first banked and flooded in large tracts, thus really returning to the basin method of irrigation employed in this district until the Arabian conquest desolated the country. As the washing proceeds the land is divided up into smaller tracts and finally drains, 31.4 inches deep, are dug every 50 meters (164 feet) in the worst land, or every 100 meters (328 feet) in land less saline. Washing is carried on as at Abukir until a stand of dineba can be secured, after which other crops are planted. Rice is used a great deal in rotation with dineba and clover. The dineba seed is sown at intervals until a stand is secured. Frequently the dineba is sown on land yet very saline and a scattering stand secured. Another sowing is then given, and so on until a good stand is secured. The land is then planted to other crops, either clover or rice, and finally to cotton. (See Pls. VI and VII.)

The inspection given this area was a hasty one, but it seemed to the writer that the reclamation was not as thorough as it should be before the land is sold.

Land is washed until it will grow one good crop and is then sold. The new owner frequently considers the soil sufficiently free from salt to grow any crop, and too often attempts to grow cotton and corn and other crops which receive relatively small amounts of water and allow large quantities to evaporate from the surface of the soil. The result has been that considerable areas once considered reclaimed are now becoming salty again, and confidence in the methods of reclamation is being shaken. The criticism is not on the methods of reclamation in use, but applies to methods used by the new owner of the land.

The most successful way to handle this newly reclaimed land is, as has been shown, to continue the reclamation, at intervals of three or five years, by introducing into the rotation some crop which will withstand large quantities of water.

The Societé du Behera, under the management of Mr. Theobold Smith, has constructed and is operating a steam leveler which is of interest and should be of use in certain portions of America. The scraper consists of an **I** girder with framework of iron for attachment power. This girder is drawn across the field by an 8-horsepower engine of the type used for steam plowing. The girder scrapes up a great quantity of soil, which is dumped where required. The machine

A FIELD WITH A SATISFACTORY STAND OF BARNYARD GRASS.

Three years ago this soil carried 8 per cent of alkali and was totally unfit for agricultural crops. This test indicates that it is completely reclaimed for such crops as clover.

FIELD OF COTTON ON NEWLY RECLAIMED LAND.

After the soil is sufficiently reclaimed for clover, cotton is planted. This picture shows a spot where the alkali is too strong for cotton, and on which dineba or barnyard grass will again be planted and the land heavily flooded for more complete reclamation.

does not thoroughly level the land, but leaves it in slight ridges and heaps, necessitating a final leveling with horse or bullock scrapers.

RECLAMATION OF SALT LAND AT BUSILI.

Through the kindness of Mr. T. S. Richmond, engineer of the Abukir Company, Limited, a visit was paid to the village of Busili, near which reclamation work was being carried on both by the natives in their own way and by Europeans following the methods in use at Abukir.

The land at Busili lies directly west of the Rosetta branch of the Nile, between the river and the salt lake Edku. The land is only a few feet above sea level and has been flooded from time to time by the Nile. Much of it has been out of cultivation for such a long time that alkali salts have accumulated at the surface and the land is sterile.

The native method of farming this land can hardly be called reclamation, for that is never accomplished except under the most favorable circumstances. Their plan is to bank the land without any attempt at underdrainage, flood it, and sow rice. The rice is sown on the surface of the water. By this method the first year's crop is often a failure, but the flooding sweetens the immediate surface of the soil and allows the rice to grow the second year and thereafter. It is extremely doubtful, however, if more than the immediate surface is reclaimed, because there is such poor underdrainage. Whenever any other crop than rice is grown, a good portion of the land develops salt and the crop hardly pays. The land is very fertile, and with underdrainage its cultivation should prove most profitable.

An attempt was made to determine the amount of salt which rice will withstand, but this could not readily be done, as it is very difficult, without special sampling devices, to collect samples of the soil covered with water. These were not at hand, so samples were collected where the water had temporarily drained off. Samples of the standing water were also examined. The water contained about 150 parts of salt per 100,000, and the soil, to a depth of 12 inches, contained about 2.04 per cent of salt. Since the rice roots extend only a few inches into the soil, and since the water is kept fresh by constant flooding, the results of the examination of the soil do not necessarily indicate that rice is an alkali-resistant crop.

The first attempt at reclamation under thoroughly efficient methods is but now being made. An area of 500 acres is being prepared by Mr. Richmond upon plans very similar to those so successfully in operation at Abukir. Here the tertiary (gata) drains are 200 meters (656 feet) long, and 84 meters (275 feet) apart. The secondary drains run directly beside the secondary canals (see fig. 4) and act as seepage drains. This method saves somewhat in ditches, the greater distance between the tertiary drains being considered allowable because the

land is not so impervious nor so saline as at Abukir. On much of the land Mr. Richmond hopes to obtain a stand of dineba during the coming winter.

There is a great deal of land of this character in Lower Egypt; that is, land which lies but a few feet above the level of the sea, yet is never covered with salt water. The reclamation of such land is being carried on in many places with success and at a profit. The problems found here are duplicated in many of our western plains and valleys, and it is certain that much similar land abandoned in America can be taken up and brought into profitable cultivation by the adoption of like methods.

The following table shows the results of the chemical analyses of samples collected near Busili. By comparison with the analyses given on pages 25, 33, and 37, the type of alkali found here is seen to be that common to the lowlands of the delta.

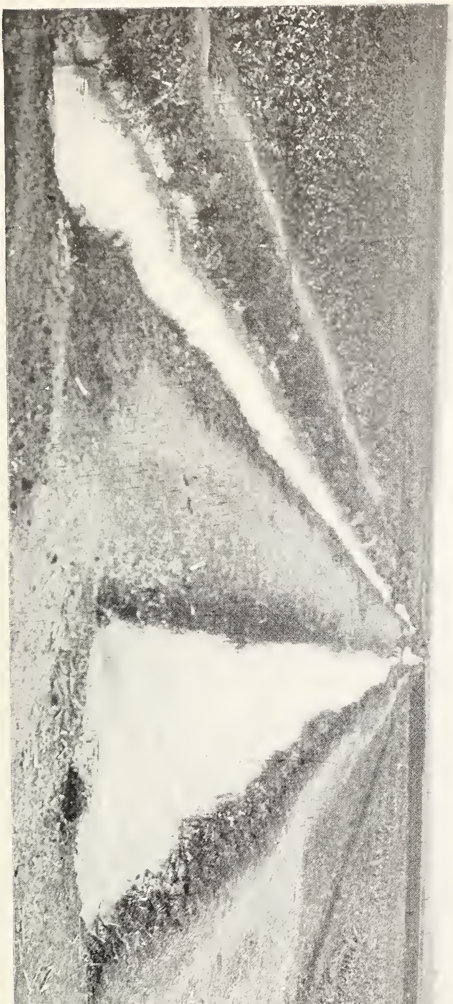
Analysis of soils from Busili.

Constituent.	7559, crust.	7547, 0 to 12 inches.	7548, 0 to 12 inches.
Ions:	*Per cent.*	*Per cent.*	*Per cent.*
Calcium (Ca)	2.69	3.33	1.94
Magnesium (Mg)	3.24	Tr.	Tr.
Sodium (Na)	30.16	26.25	30.60
Potassium (K)	1.20	10.68	5.56
Sulphuric acid (SO_4)	3.12	8.03	11.38
Chlorine (Cl)	59.23	48.19	42.98
Bicarbonic acid (HCO_3)	.36	3.52	7.54
Conventional combinations:			
Calcium sulphate ($CaSO_4$)	4.40	11.36	6.53
Sodium sulphate (Na_2SO_4)	....	....	10.04
Calcium chloride ($CaCl_2$)	3.87	....	....
Magnesium chloride ($MgCl_2$)	12.71	....	....
Potassium chloride (KCl)	2.29	20.37	10.55
Sodium chloride (NaCl)	76.23	63.49	62.59
Sodium bicarbonate ($NaHCO_3$)	.50	4.79	10.29
Per cent soluble	16.39	2.04	1.42

Sample No. 7547 was collected near Messana village, about 2 miles south of Busili station, from a rice field where the land was saline and rice just growing. This probably represents the limit for growth of rice in this type of alkali. The land at this place was not covered with water, but had been dry for a few days. The farming was being done by the native method, no attention being paid to drainage. (See Pl. VIII.)

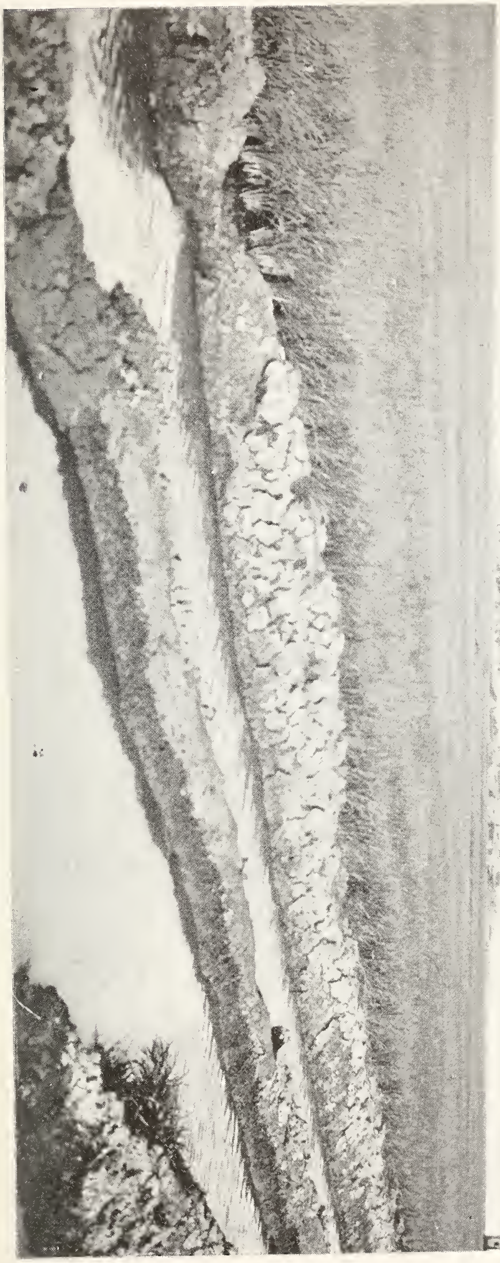
Sample No. 7548, collected near the same place, was from a cotton field, where the cotton was living. This represents the limit in quantity of alkali of this type in which Egyptian cotton will grow.

Sample No. 7559 is the alkali crust scraped from the surface of the soil.



COTTON FIELD FULLY RECLAIMED FROM ALKALI.

This shows the irrigation ditch on the right and the ever present drainage or infiltration ditch on the left, to quickly remove the seepage water.



A FIELD OF RICE UNDER NATIVE METHODS OF IRRIGATION WITHOUT DRAINAGE.

Rice, being a shallow-rooted crop and growing almost continuously in standing water, will thrive on a soil where crops requiring intermittent irrigation will not grow on account of the rise of alkali during the dry stage.

RECLAMATION WORK AT KOM-EL-AKHDAR.

Kom-el-Akhdar (Green Hill) is situated in the eastern edge of the depression in which lies Lake Mariut. The level of land around the hill is about sea level. Toward the west the land falls to the level of the present lake, which is maintained by the Egyptain government pumping station at Mex at 2½ meters (8.2 feet) below sea level. This area lies in the district famed in ancient days for its wines, and was then well cultivated and fertile. The land is now mostly charged with salt and alkali, and is practically worthless as far as profitable agriculture is concerned.

A few years ago a French company bought 10,000 acres of this land and attempted its reclamation. Of this tract 1,500 acres were already sufficiently free from salt to be brought into cultivation. These areas of good land are situated upon slight ridges which extend from the higher lands on the east out into the low delta lands on the west.

This company constructed a canal from the Nile, nearly 50 miles distant, established a large pumping station, dug canals and drains at right angles to each other, extending them all over the property, and built buildings, a church, and dwellings for the natives. Very solid brick and masonry irrigation works were installed. A pumping plant for the drains was put in and an outlet was dug. Steam machinery for farm use was bought, farm tramroads constructed, and in short the property was in every way prepared for extensive agricultural operations. Yet the land was never reclaimed from salt. It is said that £E.980,000 ($4,900,000) were spent upon the property. This is at the rate of nearly £E.100 ($500) per acre. The company reached the end of its resources, and the land has been for sale for a number of years. Recently it was sold for £E.67,000 ($335,000), or at the rate of about $33.50 per acre.

When visited in September, 1902, the property was said to contain about 1,500 acres of arable land. This was the land that was most easily reclaimed, or land which more likely never had been salty—probably the original 1,500 acres of good land. Remains of extensive ditches and canals, overgrown with weeds and filled with sediment, were seen on every hand. The stone and masonry irrigation works were falling to pieces, the church was half in ruins, and alkali weeds and salt plants were thriving on every hand.

As lessons are to be learned from every failure, as well as from every success, careful inquiry was made into the methods adopted by the company, to see if in them lay the cause of the waste of so much money. Certainly the land and the kind and amount of salt present were not to blame, for in other parts of Egypt such lands had been successfully washed and are now returning harvests of great value.

A sample of soil was collected from a spot representing an average

of the land which had not been washed, and an analysis made in this Bureau. The following table gives the result of this analysis:

Chemical analysis of alkali soil from Kom-el-Akhdar.

Ions.	No. 7555, 0 to 12 inches.	Conventional combinations.	No. 7555, 0 to 12 inches.
	Per cent.		*Per cent.*
Calcium (Ca)	3.07	Calcium sulphate ($CaSO_4$)	10.43
Magnesium (Mg)	2.00	Magnesium sulphate ($MgSO_4$)	9.90
Sodium (Na)	28.83	Potassium chloride (KCl)	3.62
Potassium (K)	1.90	Sodium chloride (NaCl)	60.88
Sulphuric acid (SO_4)	24.56	Sodium bicarbonate ($NaHCO_3$)	1.41
Chlorine (Cl)	38.62	Sodium sulphate (Na_2SO_4)	13.76
Bicarbonic acid (HCO_3)	1.02	Per cent soluble	8.2

The salts in this soil are very similar to those found at Damru (see analysis on page 37), and are thought to be characteristic of the largest areas of alkali land of Lower Egypt. If reclamation is possible at Abukir, Damru, and Kom-el-Wahal, such lands as those at Kom-el-Akhdar should be easily brought into cultivation.

As near as could be gathered the failure was due to one or all of the following causes:

(1) The ditches were not close enough together to permit ready or rapid washing of the soil. The soil is heavy and very impervious, being the finest sediment from the Nile, the last to be dropped by the water, as is all of the soil of the delta at a distance from the main channels of the river. The subsoil retains its tenacity to great depths and is everywhere charged with salt. Ditches in such heavy and impervious soil should be close together, certainly not more than 50 meters (164 feet) apart, if their effect is to be immediately felt. The efficiency of ditches varies approximately inversely as their distance apart, so that ditches 150 meters apart would act twice as quickly and be twice as effective as ditches 300 meters apart.

(2) The ditches should have taken advantage of the slope of the land and should have followed the lowest levels. Instead of following this method the ditches were run on a rectangular system, and in many cases, owing to local irregularities in the soil and to the marked ridges which run through the land, were not deep enough to properly carry away the underground water. In ditching land advantage should be taken of the topography, and the main and primary drains should invariably follow the lowest portions of the land. Canals, on the other hand, should follow the high land, so that there may be no necessity to raise the water artificially in order to irrigate the adjacent soil. If land is thoroughly protected by drains there need be no fear that seepage water from these high-line canals will injure the land.

(3) Reclamation was attempted on too large an area at once. Will-

cocks estimates that it requires four times as much water to supply an acre with basin irrigation as with perennial irrigation. When land is being washed to free it from salt the amount of water needed is at least as much as for basin irrigation. Canals in the delta are dug to supply the land with perennial irrigation, and therefore have not the capacity to supply all the land with basin irrigation. For this reason it is never safe to take up a large area for reclamation at one time. It seems that in the Kom-el-Akhdar reclamation large areas were undertaken at one time, and that the work on each of these areas could not be carried on as thoroughly as would have been possible in smaller areas.

(4) The reclamation work was not carried on as thoroughly as it should have been before cotton farming was attempted. This is an important fact about salt-land reclamation; thoroughness is essential to success. The attempt to plant crops unsuited to the soil in land half reclaimed results in a rise of salt from the subsoil, and often in great detriment to the soil.

Failure in Egypt frequently results from the owner of land under reclamation renting land partly reclaimed to fellahs. The methods of farming used by the fellahs with perennial irrigation do not further the reclamation; in fact, as a rule the land goes backward. Land in which the surface foot of soil only is washed free from salt may have every appearance of being reclaimed, and for all practical purposes is as valuable as thoroughly reclaimed land, but great care must be exercised that the underlying salts do not rise into the upper foot, where the roots are active.

This property at Kom-el-Akhdar has recently been bought, and is to be farmed by a man of wealth. New methods of reclamation are to be used, and it is hoped that success will follow.

At this point it seems pertinent to emphasize the fact that success in alkali-reclamation work depends entirely upon the thoroughness with which the work is done, and upon the persistency with which the one idea of getting rid of the salt in the surface soil, and keeping that in the subsoil from rising, is adhered to. Reclamation attempted by a stock company is very apt to be hurried, in order that dividends may be paid promptly. Should reclamation work be undertaken in this country, this fact should be kept in mind, and during the first few years stockholders should not expect to receive profits.

ALKALI-LAND RECLAMATION IN UPPER EGYPT.

The land of Upper Egypt is, in the main, still irrigated by the old basin method. As rapidly as possible, however, these basins are being converted into land under perennial irrigation. The change was instituted by the Khedive Mahomet Ali many years ago. This Khedive owned large tracts of land in Upper Egypt, and in the readjustment

of the finances of the country under the reign of Ismail these personal estates were turned over to the government in payment of debt. The Daira Sania administration has control of these lands at the present time.

During the last forty years much of this land has been allowed to lie idle. Under the basin method of irrigation, water stood on the land from six to eight weeks each year, thus thoroughly washing the soil and preventing the accumulation of a harmful quantity of soluble salts. When, however, it was allowed to lie idle, the slow upward capillary movement brought to the surface the salts which were formerly never present there in any great quantity, but which were scattered through a great depth of soil. The analysis of Sample No. 7551 shows the character of the surface foot of soil after being out of cultivation forty years. The analysis of Sample No. 7560 shows the character of the salts collected from the surface of the soil at another place.

Analyses of soils from near Magaga.

Constituent.	7560, crust.	7551, 0 to 12 inches.
Ions:	*Per cent.*	*Per cent.*
Calcium (Ca)	9.40	12.39
Magnesium (Mg)	8.31	3.65
Sodium (Na)	14.19	17.50
Potassium (K)	1.27	2.15
Sulphuric acid (SO_4)	10.28	11.07
Chlorine (Cl)	55.94	51.98
Bicarbonic acid (HCO_3)	.61	1.24
Conventional combinations:		
Calcium sulphate ($CaSO_4$)	14.56	15.69
Sodium sulphate (Na_2SO_4)		1.72
Calcium chloride ($CaCl_2$)	14.61	21.49
Magnesium chloride ($MgCl_2$)	32.59	14.31
Sodium chloride (NaCl)	35.44	43.24
Potassium chloride (KCl)	2.41	3.55
Sodium bicarbonate ($NaHCO_3$)	.54	1.72
Per cent soluble	17.61	7.71

One peculiarity brought out by these analyses is the presence of large quantities of calcium chloride. This salt, from its tendency to absorb moisture from the air, keeps the surface of the soil moist all of the time. A sample kept in a cloth sack in the hotel room at Cairo absorbed so much moisture as to drip and form a pool of water.

This type of alkali seems to be characteristic of much of the desert land lying on each side of the Nile in Upper Egypt. Mr. Willcocks, of the Daira Sania, called attention to the fact that all along the Nile Valley soluble salts were present in quantity in the rocks of the desert hills. These hills were examined in a number of places and everywhere salts were found to be present. One sample was collected from

the surface of the desert about 4 miles east of Helwan. The analysis of this sample appears in the following table:

Analysis of alkali soil from desert east of Helwan.

Ions.	Sample 7562.	Conventional combinations.	Sample 7562.
	Per cent.		*Per cent.*
Calcium (Ca)	28.54	Calcium sulphate ($CaSO_4$)	43.75
Magnesium (Mg)	1.11	Calcium chloride ($CaCl_2$)	43.34
Sodium (Na)	1.49	Magnesium chloride ($MgCl_2$)	4.37
Potassium (K)	2.31	Sodium chloride (NaCl)	3.03
Sulphuric acid (SO_4)	30.89	Sodium bicarbonate ($NaHCO_3$)	1.09
Chlorine (Cl)	34.87		

Thus it would seem that the soluble salts which occur in the desert on each side of the Nile are mainly compounds of lime and magnesium. Out in the valley these salts are mixed with and modified by those salts carried in solution in the Nile water, resulting in the formation of alkali salts of the type already described.

Through the kindness of J. Birch Bey, inspector for the Daira Sania administration, a visit was made to the estates around Magaga and between that place and Fechn.

At the time reclamation was commenced there were 15,000 acres of land idle and charged with alkali. Birch Bey estimates that the cost of reclamation will be £E.30,000 ($150,000), and that the rental from this area when reclamation if completed will be £E.70,000 ($350,000) per annum.

The method of reclamation pursued is different from that in use in any other part of Egypt. The fundamental idea is a return to basin irrigation. Preliminary to washing the soil the land is leveled thoroughly. Steam plows are used to loosen the soil and bullock scrapers to move the loosened material, obliterating all unevenness, so that the soil may be easily and uniformly flooded. A great deal of the alkali is found on the immediate surface of the soil. Advantage is taken of this fact, and in the process of leveling the surface accumulation is scraped up and carried to the edge of the field to build dikes. Such a proceeding removes part of the salt, but this direct method could only be practicable in a country where labor is cheap.

The drainage ditches are about a mile apart and tail into one large ditch. These ditches are mainly of service as surface drains—that is, their use is practically limited to the removal of surface water. Their effect as underdrains is limited to the land immediately along the drains.

Upon the completion of leveling, ditching, and diking, the land is flooded to a depth of from 4 inches to 1 foot. This depth of water is maintained until the land is thoroughly sweetened, which requires from one to four years. The slowness of the work is due to the lack

of adequate underdrainage. Were ditches more frequent it is thought that a more rapid sweetening of the soil would result.

One feature in the reclamation work being carried on by Birch Bey is worthy of imitation in all work of this character—that is, thoroughness. Land once thoroughly reclaimed gives no further trouble from alkali if farmed with intelligence, but land partially reclaimed reverts to its damaged condition in a few years. It has been found more economical to wash land four years and be sure of thorough reclamation than to attempt the cultivation of half-reclaimed soil, which invariably develops salt spots that spread from year to year.

Upon the completion of the reclamation, cotton, corn, clover, alfalfa, sugar cane, and all crops grown in the district can be grown without fear of a rise of alkali, but the partially reclaimed land is fit only for alkali-resistant crops, or crops which will grow in standing water.

This method of alkali-land reclamation can only be used to advantage in areas where the depth to standing water is great; there must be sufficient depth of soil into which the excess of alkali can be washed. Where standing water is close to the surface, as in much of the alkali lands of lower Egypt, there is no place into which the salts can be washed, and underdrainage is necessary.

SUMMARY OF RECLAMATION METHODS.

There are three methods of alkali-land reclamation in use in Egypt. Each of these methods is successful under the conditions appropriate for its use, and all are worthy of being tried in America.

Colmatage or warping.—This method of reclamation consists simply in flooding land with muddy water long enough to allow the mud to settle, after which the clear water is drawn off and more muddy water run on. Very little attention is paid to drainage, except in so far as surface drains are dug to carry away the clear water. The popular impression prevails that by this method the alkali or salt is covered up with sufficient good soil to permit plant roots to thrive. As a matter of fact, the efficiency of the method depends much more on the fact that the alkali is washed down into and mixed with the subsoil, so that its concentration at the surface is diminished. The total amount of alkali in the soil is very slightly reduced, and when conditions again become favorable for the rise of the alkali it returns to the surface and proves as troublesome as before. Where, however, the depth of soil and subsoil above standing water is great, and where rice or other wet-land crops are to be grown, colmatage may advantageously be used for reclamation. Large quantities of water are required and much land is made swampy. As an efficient and permanent remedy for alkali land this method can not be recommended for general use.

Flooding with open drains.—This is the method in common use in Egypt. The land is thoroughly leveled, open ditches to a depth of 32

inches are dug at intervals of 150 to 450 feet, and the land is banked up and flooded to a depth of 4 inches until sufficiently leached of alkali or salt to permit plant growth. This method is thoroughly effective for the removal of salt, but it has the objectionable feature of open ditches.

Flooding with tile drains.—This method has only been tried experimentally in Egypt, but promises to be the most rapid and effective way of reclaiming the land. Tile drains are placed 30 inches deep and 35 feet apart, at a cost of $30 per acre.

Application to American conditions.—In applying these methods of reclamation to American conditions there are a number of factors which enter into the problem and make necessary certain changes. American farmers have a well-grounded dislike to open ditches in fields. They take up a large amount of valuable land, require an annual outlay in cleaning and deepening, necessitate the building and annual repair of bridges, and prevent or hamper the use of machinery in agricultural operations. Tile drains take up no room, render no land unavailable for cropping, require little or no repairs if properly laid at the start, and are efficient for many years. One hundred feet of open ditch 7 feet wide occupies 700 square feet of land; the value of this, at $100 per acre, would be $1.61. The cost of digging 100 feet of open ditch of this width, 3 feet deep, is at least $4. The cost, in our Eastern States, of digging, laying tile, filling the trenches, and purchase of 4-inch tile for 100 feet of drain is about $4, so that there is a difference of $1.61 per 100 feet in favor of the tile. If allowance is made for cost of bridges and annual cleaning of open ditches, the difference will be still greater.

The soils in arid America are generally light in character and do not stand well in bank, so that great trouble would be experienced in maintaining small open ditches.

For these reasons alkali land reclamation by means of open ditches is not to be recommended for general use. In the larger drains, where very large pipe would be required, open ditches may be used, but in a great many localities some kind of protection will be necessary to strengthen the banks and prevent their caving.

The irrigation season, except in certain parts of California and Arizona, is shorter than in Egypt, and in order to reclaim land within a reasonable length of time it will be necessary to place drains closer together. In this way the land will be reclaimed in a shorter time, because a greater quantity of water can be run through the soil in a given time. In an experiment on 40 acres now being carried on in a loam soil near Salt Lake City, Utah, the tile were placed 150 feet apart. This seems to be a good average distance at which to place tile. As the experiment progresses more definite information regarding the time required for reclamation can be given.

It is hardly practicable to recommend the use of such crops as dineba, samar, and rice in America for use during reclamation, but sorghum, certain of our native grasses, alfalfa, and possibly in California and Arizona, Egyptian clover may be substituted to suit the conditions. As the experimental work progresses other and more satisfactory crops may be found.

Pumping for the removal of drainage water is very expensive. It is so considered wherever used, though frequently conditions make it profitable. Pumping from large drainage systems has certain very definite limitations, and wherever possible a gravity outlet should be dug. Often a gravity outlet proves very expensive to install, but unless there are great difficulties in the way it will be found cheaper and more effective in the long run.

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